IV. *On Intestinal Absorption, especially on the Absorption of Serum, Peptone, and Glucose.*

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Introduction.

Since the days of Lieberkühn it has been the laudable desire of the physiologist to maintain the thesis that the process of absorption of solutions from the intestine is explicable upon some simple physical basis.

To an assertion, however, that at the present day the details of the process are within our grasp, few who have studied the literature of the subject and the thing itself, will be prepared to give unqualified assent.

Nor need it be matter for surprise that the question is still *sub judice*, for in addition to the difficulty common to all physiological problems, and most prominent in the one before us, viz., the elimination of factors unessential and disturbing, but present by the nature of the case, it must be remembered that any real knowledge of the physics of solutions is essentially of recent date, and that its application in physiological research has frequently, through misapprehension of fundamental points, tended not a little to confuse the issue.

I deem it of little profit in this place to enter at any length upon the theories of intestinal absorption propounded by physiologists in the earlier part of this century, for not only was a knowledge of the physical condition of substances in solution then non-existent, but the very structure of the wall of the intestine was but imperfectly recognised.

Rudolphi and Magendie were both of opinion that "imbibition" was the cause of absorption, while Tiedemann and Gmelin with, as far as one can discern, but little basis for such a theory, compared the absorbing villus to an inverted secreting gland.

With the advent of the elementary knowledge of osmotic phenomena inaugurated by the researches of Fischer and Dutrochet, the *rationale* of the motion of solutions through the wall of the gut seemed, naturally enough, to have been definitely established, and an osmotic explanation in full simplicity held the field almost unquestioned for many years, and in modified form is current at the present day.

Brücke, however, in 1852, still maintained the theory promulgated a century or so

before his time by LIEBERKÜHN, viz., that the contents of the intestine are filtered by peristaltic pressure through the wall of the gut into the vessels of the villi.

A physiologist in the early sixties had then open to him, as a physical basis upon which to build a theory of intestinal absorption, considerable knowledge of the processes of filtration, osmosis and diffusion, for the work of GRAHAM had now been added to that of the followers in the immediate steps of DUTROCHET.

Since, moreover, LUDWIG'S discovery of secretory pressure was now matter of common knowledge, and the histology of the gut wall was, thanks to the researches of BRÜCKE, KÖLLIKER, BRETTAUER and STEINACH and others, well advanced, the possibility of some special cell action concerned in the motion of the fluid absorbed, was also before the theorist. JOHANNES MÜLLER had, indeed, as early as 1841, asserted that the cylinder cells discovered by HENLE exerted in the process of absorption an "organische Anziehung."

No attempt was, however, for some time made to apply the idea of LUDWIG'S discovery to the process of intestinal absorption, and in 1869 we find VOIT and BAUER explaining the absorption of *serum* from the intestine, which they were the first to observe, purely upon the filtration theory advocated by BRÜCKE. Indeed, not till 1881 do we find grave doubts expressed by HOPPE-SEYLER of the adequacy of osmosis and filtration to account for all the phenomena of intestinal absorption, and the suggestion very definitely thrown out that the cylinder cells play an active part in the process.

HOPPE-SEYLER considered the following two points as evidence against osmotic absorption, viz., that weak alcohol is rapidly absorbed, and causes no passage of water from the blood into the gut; and that in cholera, where the epithelium of the intestine is largely shed, absorption is at a standstill, although the concomitant thinning of the membrane would appear to be in favour of osmotic transfer.

As will be evident immediately, neither of these observations militates against an osmotic explanation, any more than they prove an *active* interference on the part or the epithelium.

Against the filtration theory, HOPPE-SEYLER urged that for filtration to occur with ease the filtering membrane must retain its configuration under pressure, a condition impossible to realise in the case of the soft easily-deformed epithelial layer, and further, that if filtration is to be produced through such a membrane, a far higher pressure would be requisite than peristalsis with continuity of the gut lumen could be expected to produce.

The full significance, in all physiological problems involving an appeal to the process of osmosis, of the relation of the nature of the substance in solution to the nature of the membrane is of such comparatively recent recognition, that it is no uncommon occurrence to note in the works of the older writers on the subject of intestinal absorption, that a phenomenon adduced as evidence against an osmotic explanation, has really no such import at all. Until TRAUBE discovered membranes permeable by

the solvent but not by the substance in solution, the phenomenon originally observed by DUTROCHET with dead animal membranes (permeable, but in different degree, by both solvent and dissolved substance,) of an *endosmotic* current of solvent and *exosmotic* current of dissolved substance, was held to be characteristic of all osmotic processes. It was at first considered that a fixed amount of dissolved substance must necessarily enter the solvent from the solution for a certain amount of solvent passing in the opposite direction. The idea became "crystallised" in the term *endosmotic equivalent* of the substance in solution.

Research soon showed that this ratio had no constant value, but only one relative to the special membrane used for experiment, and moreover to the time during which the particular membrane had been subjected to alteration of its physical condition by contact with the solution in use. If the labour spent upon the determination of endosmotic equivalents was of little value, there is no doubt that the investigations impressed the great difference in permeability to dissolved substances exhibited by different dead animal membranes, an elementary point to be grasped by any student of an absorptive process.

In order to decide the course of events when a solution of a certain substance is separated from the solvent by a given class of membrane, the first point to determine is naturally the degree to which the membrane is permeable by the substance in solution.

This is not the place to enter upon theories of the physical basis of permeability, but it must be stated that there is no real foundation for the original idea of TRAUBE that the "size of the molecules" is the determining factor. Salts highly dissociated in solution were shown by OVERTON to be unable to penetrate the protoplast of the vegetable cell, while complex organic substances pass through, and every histologist is aware of the great impermeability of the membrane of the red blood corpuscles to sodium chloride, while urea easily gains admittance to the interior of the cells.

HOPPE-SEYLER'S points against osmotic absorption from the intestine will not bear investigation. We know that the gut membrane is easily permeable by alcohol, and weak alcohol may easily diffuse over into the blood vessels of the villi without any "extraction" of water therefrom. Were the gut membrane very impermeable to alcohol, as it is, for instance, to magnesium sulphate, the result would not be as it is. Again, that the loss of the gut epithelium in cholera puts an end to the absorption of solutions different in composition to the blood plasma, does not necessarily prove that the epithelium actively transfers the solutions into the blood in the normal state of affairs. The explanation of the result might be that the epithelium is a barrier, physically impermeable to certain substances in solution in the plasma and exerting osmotic pressure, and that with removal of the barrier such substances can diffuse over into the gut, so that the value of their osmotic pressure as a factor in absorption of water is annulled.

In recent times the most energetic support to the theory that intestinal absorption

is, in part, at any rate, an active physiological function, has come from Breslau. The late Professor HEIDENHAIN himself and his pupils, LEUBUSCHER, GUMILEWSKI, and RÖHMANN published five memoirs on the subject, in all of which the adequacy of osmosis to explain all cases of absorption is doubted. The experiments of GUMILEWSKI and RÖHMANN were carried out upon dogs provided with intestinal fistulæ, while those of HEIDENHAIN and LEUBUSCHER were performed with freshly prepared loops of gut.

The points advanced by LEUBUSCHER against a purely osmotic theory of absorption were: that the water of weak (·25 per cent. to ·5 per cent.) solutions of sodium chloride is absorbed more readily than is distilled water itself. That though the absolute amount of sodium chloride absorbed rises with the concentration of the solution placed in the gut, the quantity absorbed relative to that introduced, falls as the concentration of the solution introduced is raised. He found 50 per cent. of the total sodium chloride of a 1 per cent. solution absorbed, as against 35 per cent. of the salt when the concentration was 5 per cent.

Finally, contrasting potassium and sodium chloride in solutions of equal concentration he found sodium chloride absorbed faster than potassium chloride, in the inverse order of the diffusibilities of the salts as determined by GRAHAM.

It cannot be admitted that these points are in any way convincing of the presence of a special cell action.

Distilled water may injure the intestinal membrane in a manner not occasioned by weak salt solution, and the alteration may lead to diminished permeability to water, or more probably to increased permeability to plasma constituents, by virtue of the osmotic pressure of which water is normally removed from the gut. Some similar effect may be produced by the strong salt solution (5 per cent.) affecting the ease of diffusion of salt out of the gut into the blood, by alteration of the gut membrane.

The argument with potassium and sodium chloride can have no weight, since the coefficients of diffusion of these substances were obtained by GRAHAM under totally different conditions. WALLACE and CUSHNY, in a recent investigation, found no difference in the rate of absorption of these two salts.

The paper of LEUBUSCHER is, however, of value in other ways. He demonstrated the reliability of the method of comparing absorptions in two loops of intestine in one animal, the method used in my own investigation, and furthermore there are important observations on the effects of hydrostatic pressure both upon absorption and upon the circulation in the wall of the intestine. These will be referred to later.

GUMILEWSKI confirmed the statement of LEUBUSCHER that water is more easily absorbed from solutions of sodic chloride of concentration (·25 per cent.) than from a supply of distilled water in the gut, and further noted that sodium chloride is absorbed from solutions of lower concentration in the salt than the blood plasma itself. At a concentration of about ·6 per cent. of sodium chloride, he found the salt and

water absorbed at the same rate, while at 1 per cent. the salt was absorbed faster than the water.

His points concerning the equality in the rate of absorption of salt and water at a certain concentration of the introduced salt solution, and the absorption of salt from solutions of lower concentration in salt than the blood plasma, were insisted upon by HEIDENHAIN in support of the theory of cell action. Their discussion will for the moment be adjourned until a more detailed consideration of the phenomena is convenient.

One other point in GUMILEWSKI'S memoir must, however, be here considered. He maintained that the quantity of *succus entericus* secreted during the experimental period can be gauged by the amount of sodium carbonate present in the fluid removed from the fistulous loop of gut, because he found the concentration of this salt (and also of sodium chloride) remained very constant in the *succus* secreted from day to day, when no experimental absorption was proceeding.

RÖHMANN, however, who used one of GUMILEWSKI'S animals among others, could only find this constancy in sodium carbonate in the case of a short (11 centims.) loop which had been in communication with the air for over a year, and saw great irregularities in the concentration of sodium carbonate in the *succus* of more recently established and longer fistulous loops. v. SCANZONI has also been unable to confirm the regularity, and the recent experiments of O. COHNHEIM also show very great variations in the sodium carbonate added in equal periods of time to solutions of glucose placed in the loop, and, moreover, no relation between the amount of sodium carbonate secreted and the concentration of the glucose solution filled in, provided the latter be not strong enough to injure the gut wall.

As HEIDENHAIN points out, the secreted *succus* is by no means the sole source of the sodium carbonate found in the loop at the end of an experiment—some may arise from the mucus of goblet cells and some may diffuse* in from the blood if the gut wall is injured.

There is probably no accurate method of estimating the amount of *succus entericus* secreted during an absorption experiment. Both BIDDER and SCHMIDT, and VOIT and BAUER saw no accumulation in loops tied off for a few hours, and in fistulous loops, when the animal has fasted for a day, only a few grammes are formed in an hour, so that it appears reasonable to act on the supposition that bland, non-irritating fluids do not evoke any special activity of LIEBERKÜHN'S glands, and that the quantity of fluid secreted is so small in relation to the large volumes of introduced solution absorbed as to be negligible. EDKINS, using ·6 per cent. solutions of sodium chloride, could not convince himself of any considerable secretion of *succus entericus* in the

* Though not strictly accurate, seeing that a membrane intervenes, the term *diffusion* is used in this paper to mean the passage of a substance in solution through a membrane, from a seat of higher to a seat of lower partial osmotic pressure of the substance, under the conditions of physical permeability of the membrane to the substance in question.

freshly-prepared loops in the cat, and HEIDENHAIN, who did not attempt to calculate the *succus* secreted, arrived at practically the same results as GUMILEWSKI who did.

RÖHMANN continued GUMILEWSKI'S work on the same lines, but used nutritive substances, viz., starch, cane sugar, glucose, and peptone.

The absorptions of peptone were estimated by means of the polarimetric observation of the solution removed from the gut, so that no high grade of accuracy was attained.

Of the four substances used, viz., grape sugar, cane sugar, peptone, and starch, the order of rapidity of absorption was found to be that here set down.

Cane sugar was found to be absorbed at about ten times the rate of sodium sulphate, and RÖHMANN considered this as evidence in favour of epithelial action, because C. E. HOFFMANN, in experiments upon the dialysis of these substances through ox pericardium into water, had found that sodium sulphate passed through this membrane rather faster than cane sugar.

The gut wall was also found to be more permeable to grape sugar than to sodium sulphate. As in the old experiments of v. BECKER and FUNKE, it was found that with increase of concentration of the solution in the gut the absolute amount of dissolved substance absorbed increased, but with grape sugar he states that a maximum concentration is reached at the level of 5 per cent. or 6 per cent., beyond which an increase does not occur.

He also noticed that with all four substances the absorption during a second hour was less than that during the first.

A year after the publication of RÖHMANN'S work appeared the first of HEIDENHAIN'S papers. A large part of the paper is taken up with a renewed histological investigation of the gut wall, which will be referred to incidentally only in the following pages.

In the physiological section of the work we note the following :—

The fact is clearly demonstrated that the main absorption of solutions from the gut cavity is by the blood capillaries of the villi, which form such a dense network immediately below the epithelium. The flow from the thoracic duct is but slightly increased when the whole of the animal's small intestine is distended with fluid which is being rapidly absorbed, and if the gut is not distended no increase in the outflow of lympth is noted. GINSBERG and WERTHEIMER have also shown that it requires a great excess of sugar or indigo-carmine solution in the gut to obtain evidence of the presence of these substances in the fluid flowing from the thoracic duct.

It is further demonstrated by injections of solutions of methylene blue into the intestine of the frog and subsequent microscopic investigation, that substance in solution can reach the blood vessels in two ways, viz., in the cement substance between the epithelial cells and through the protoplasm of the cells.

On the other hand, little new evidence in support of the theory of epithelial action is adduced, and that which is quoted is decidedly weak.

The rate of absorption of water by the gut is compared with the rate of passage of water through a layer of ox bladder to defibrinated blood, and found in the first case to be at about twenty-nine times the rate in the second. The relative permeability of the two membranes to the substances in blood exerting osmotic pressure is not even hinted at, and since the blood salts are known to rapidly diffuse through ox bladder, and no stirring or renewal of the water was attempted, the result obviously proves nothing so far as the point before us is concerned.

That the slow absorption of serum and egg albumen from the gut is not due to their slow rate of diffusion is asserted, on the grounds that these substances easily pass through other membranes in the body, in the formation of lymph in one case and in the excretion of injected egg albumen by the kidney in the other. Here, not only are two different classes of membrane compared, but the possibility of simple filtration being the cause of passage of albumen through the capillaries is not considered.

At the time of the publication of HEIDENHAIN'S second paper, some five years back, the generalisations of VAN'T HOFF and ARRHENIUS upon the physics of solutions were thoroughly current, and the subject is attacked from the modern standpoint of knowledge of osmotic phenomena.

The experiment of VOIT and BAUER of the intestinal absorption of serum was repeated, and analyses, in two cases, of the serum before and after its residence in the gut indicated that the water and salts were absorbed at the same pace, the organic solids more slowly. The experiment succeeded even when the serum was artificially inspissated. HEIDENHAIN concluded that this phenomenon could not possibly be explained by osmosis, but he did not consider the possibility of filtration.

A prolonged study of the absorption of solutions of sodium chloride at different concentrations is presented, and the effects upon the absorption of solutions of this salt of small additions of sodium fluoride, a substance introduced now for the first time as an agent for injuring the gut epithelium, is considered at length.

Since salt and water were found to be absorbed at the same rate from serum, and since, according to HEIDENHAIN, such absorption can only be brought about by epithelial action, he concludes that in all absorptions of salt solutions of whatever concentration, a part is exclusively *physiological*, and that when a solution of sodium chloride, of blood concentration in that salt, is absorbed from the gut, it is passed over as such by the action of the cells.

If the salt solution be of concentration above that of the blood in sodium chloride, and of higher osmotic pressure than the blood plasma, part of the salt absorption is attributed to diffusion, *i.e.*, that part of the absorption over and above the amount supposed to be transferred by the cells, while the water absorption is supposed to be entirely due to cell action.

If the concentration of the salt solution is below the plasma level in sodium chloride the salt absorption is considered as exclusively due to cell action, because sodium chloride passes from a seat of lower to a seat of higher partial osmotic pressure of the salt in solution; the water absorption is considered as partly physical on account of the higher osmotic pressure of the plasma, but part is ascribed to the action of cells.

HEIDENHAIN reasoned that if with "super-normal"* solutions of sodium chloride the water absorption, and with "sub-normal" solutions the salt absorption is exclusively due to cell action, a protoplasm poison like sodium fluoride should have different results in the two cases.

In the case of the "super-normal" solution it should reduce the absorption of water disproportionately to that of salt, and *vice versâ* the salt absorption disproportionately to the water absorption, in the case of "sub-normal" salt solutions.

Such he found to be the case, and further that the action of the fluoride was only slowly recovered from.

The points advanced in favour of a physiological "triebkraft" were :—

1. The absorption of a solution of the same composition as the blood plasma, viz., serum.
2. The passage of water to the blood from sodic chloride solution in the gut, when the osmotic pressure of the solution exceeds that of the plasma.
3. The passage of salt to the blood from sodic chloride solution in the gut, when the partial pressure of the solution in sodic chloride is below that of the blood.

Of these three the first alone can stand, and then only when it has been definitely proved that absorption by filtration can be excluded.

As regards the other two the following remarks may be made in passing :—

HEIDENHAIN takes no account of the permeablity of the gut wall to dissolved substances, and even goes so far as to calculate the pressure overcome by the gut wall mechanism from the freezing points of the solutions on either side, determinations which only give a gauge of the total osmotic pressure as exerted against a membrane absolutely impermeable to the substances in solution while permeable to the solvent. To state, as he does, that the pressure overcome by the "triebkraft" exerted by the cells is 2·7 metres of mercury because water is taken up by the blood with a lowering of freezing point of ·6° C. from a solution of sodium chloride with a lowering of freezing point of ·9° C., is to utterly disregard what he himself knew, namely, that the salt of the solution of lowering of freezing point ·9° C. rapidly passed over to the blood through a permeable membrane.

His second point has no value as proving the presence of epithelial action, for after the excess of salt has diffused over to the blood, it is possible for other substances in

* The term "normal" is here not used in the chemical sense but as meaning a solution of salt of the same concentration in salt as the circulating plasma.

solution in the plasma, and to which the gut wall is impermeable, to effect by osmotic action an uptake of the remainder of the solution.

A similar criticism may be passed upon the third statement. Water can be absorbed from the solution by osmotic action and when the sodic chloride solution has thereby been concentrated to plasma level, its absorption can be effected by the osmotic pressure of other substances in solution in the plasma, provided they cannot get out into the gut.

With a membrane so permeable to sodic chloride as the wall of the gut is from the gut side to the blood side, and permeable to water in both directions (as we know from the action of cathartic salts), an osmotic explanation of absorptions of solutions of sodium chloride is to hand whether the solution be hyper-, iso-, or hypo-tonic.

As regards the action of sodium fluoride, it certainly demonstrates that a normal condition of the gut wall is necessary for absorption, but in the light of O. COHNHEIM'S results to be detailed below, it is evident that injury to the gut wall allows the sodium chloride of the plasma to enter the gut, and this fact may be utilised to explain many of HEIDENHAIN'S results without resorting to the assumption of a special "triebkraft," though on the other hand the necessity for physiological integrity of the gut membrane is as pressing as ever.

Seeing that sodium chloride is a plasma constituent, it is obviously not an ideal substance to employ in experiments on intestinal absorption, for it is difficult to decide whether any excess of sodium chloride left behind in one experiment, over that in another, is due to diminished absorptive activity, or simply to diffusion in from the plasma under the special conditions of the experiment.

Yet another instance may be quoted to impress how imperfectly HEIDENHAIN had grasped the osmotic possibilities in the gut. GUMILEWSKI had observed that water was more slowly absorbed from solutions of sodium sulphate than from solutions of sodium chloride of equal concentration. HEIDENHAIN noted the same fact with solutions of magnesium sulphate, and considered that because a solution of magnesium sulphate had the same freezing point as a solution of sodic chloride, both should be absorbed at the same rate. Though his own analyses show that the gut wall is much less permeable to magnesium sulphate than to sodium chloride, he concluded that the slower absorption of water from the magnesium sulphate solution, especially when he used it at lower molecular concentration than the sodium chloride, was evidence that the magnesium sulphate reduced the physiological activity of the epithelial cells.

HAMBURGER recently attempted to resuscitate the filtration theory of LIEBERKÜHN. After bringing forward experiments demonstrative of the fact already established by LEUBUSCHER, that slight intra-intestinal pressure (·37 to 10·36 millims. Hg, *i.e.*, 5 to 140 millims. of ·9 per cent. solution of salt in HAMBURGER'S experiments) favours absorption, he goes further, and maintains that *if the intra-intestinal pressure is zero*, absorption of a solution of ·9 per cent. salt (iso-tonic with the blood by the blood

corpuscle method of estimation) is absolutely at a standstill. It is, in fact, maintained that the normal absorption of a ·9 per cent. solution of salt by the intestine is a simple matter of filtration.

It is unfortunate that HAMBURGER overlooked the fact that at equality of hydrostatic pressure on the two sides of an animal membrane permeable to sodic chloride (as is the gut membrane from the lumen side) the water of a ·9 per cent. solution of salt *does* move towards serum, and it is little surprising that he did not note this effect in a loop of gut drawn over a cage of aluminium wire, in which case the circulation is liable to be seriously reduced, and that he got evidence of absorption when, by slight internal pressure, the mucosa was lifted off the cage and the conditions for good circulation restored.

Further, the results are in no way convincing, *qua* a demonstration of filtration, in that the relation of the quantity of fluid absorbed to the pressure employed, is far more out of proportion than is seen in the case of actual filtration experiments through animal membranes, especially in those of TIGERSTEDT and SANTESSON with "gold beater's skin."

In only a single case is the pressure used (230 millims. of ·9 per cent. solution of salt = 17·02 millims. Hg) in excess of the pressure in the veins in the mesentery of a fair sized dog, and certainly in all cases well below the capillary blood pressure in the villi.

The author further contradicts himself at the end of the paper, where, with the loop of gut in the belly and supplied with its aluminium cage to prevent any rise of internal pressure from peristalsis and respiration, some 40 per cent. to 50 per cent. of the ·9 per cent. solution of salt is stated to have been absorbed in half-an-hour.

We are told that by "imbibition" and pressure (the result of respiratory movements, peristalsis and gravity) the gut fluid reaches the capillaries of the villi, and that then the "mitschleppende Wirkung" of the blood (say of sp. gr. 1060 and velocity 1 millim. per second) carries the fluid away.

This "mitschleppende Wirkung" must indeed be small when, according to the author, at zero pressure in the gut, and with "imbibition" still in action, absolutely no absorption occurs.

In two experiments HAMBURGER also shows that there is a slight disappearance of serum introduced into the gut of a dead dog (25 hours and 4 hours *post mortem*). The difference between the rate of disappearance in the dead dog and the rate of absorption of serum in HEIDENHAIN'S experiments is of course great. Thus per centimetre of gut per hour HEIDENHAIN saw absorptions of from ·25 cub. centim., to 1·72 cub. centims., while in HAMBURGER'S two experiments the rate is ·048 cub. centim. to ·125 cub. centim., the smaller number being in the dog which had been dead the longer.

The loop from which the greater disappearance of serum was noted was distended since 36 cub. centims. serum were placed in a loop less than 29 centims. in length,

while in the other experiment 40 cub. centims. were placed in a loop 59 centims. in length.

To which of his three factors HAMBURGER ascribes the loss of serum is not evident in the text. There is no blood pressure in a dead dog, and hence filtration is possible. Imbibition is possible, but "mitschleppende Wirkung" is absent. Indeed a combination of filtration and soakage is the most probable explanation, but the condition of the gut wall, especially of the epithelium, is so utterly different to normal that it is difficult to see any *raison d'être* for the experiment at all.

Experiments are also quoted on dead dogs with solutions of sodic chloride, but without any artificial circulation through the capillaries as in the experiments of O. COHNHEIM to be quoted below. Since the results are dealt with, and the conclusions refuted by O. COHNHEIM, it is unnecessary to enter into them here, except to mention one instance as indicating how utterly different the conditions are in the dead and the living. 80 centims. of dead gut (24 hours *post mortem*) are stated to have absorbed 18 per cent. of the water of a 1·5 per cent. solution of salt in 2 hours, while in 5 hours, practically the same amount (21 per cent.) was absorbed from a ·5 per cent. solution.

We cannot close the criticism of this paper without reference to a serious misquotation. On pp. 435 and 436 LEUBUSCHER is quoted as stating that 80 to 140 millims. of *mercury* is the optimum intra-intestinal pressure for absorption. A reference to LEUBUSCHER'S paper (p. 828) shows that in the original this is *water* pressure (*i.e.*, 5·88 to 10·29 millims. Hg), and that at about 100 millims. of *water* pressure in the gut, the outflow from a mesenteric vein begins to fall off.

LEUBUSCHER ascribed, and we think rightly, the favourable effects of moderate intra-intestinal pressure on absorption to unfolding of the gut, so that the absorbing surface is increased. Above the optimum pressure, absorption falls off on account of reduction of circulation, below the optimum, it likewise falls off, but from diminution of working surface. EDKINS also considers that 100 millims of water pressure gives the most favourable results.

The most recent contributions to the subject of intestinal absorption, by HÖBER, O. COHNHEIM, and WALLACE and CUSHNY have dealt largely with the critical point of the permeability of the intestinal membrane to different substances, and the effect of variations in the physiological condition of the gut wall upon such permeability.

HÖBER'S work impresses the importance of the relation of the substance in solution to the gut wall, and indicates clearly that the difference in result got with solutions of the sulphate and chloride of sodium is due to the fact that the gut wall is far less permeable to SO_4- than to Cl-ions. Studying the permeability to a number of ions he finds that Am- and NH_4-ions pass easily, while those of Mg are absorbed with great difficulty. He has difficulty in explaining the ease with which sodium chloride is absorbed seeing that the "plasmahaut" of plant cells and red blood corpuscles are so impermeable to this salt, and hints that it passes between the cells of the gut epithelium in the cement substance.

His results are in many respects confirmed by WALLACE and CUSHNY. They find further that oxalates are as little absorbed as fluorides, and appear to injure the gut in the same manner.

The salts used in their experiments are differentiated into two main groups, the one capable of permeating the gut wall with ease, the other with great difficulty, and some explanation of this fundamental distinction is sought. They consider that, with several exceptions, there is a relation between the behaviour of the ions in the intestine and the solubility of the corresponding calcium salts, and conclude that acids forming insoluble salts with calcium act as cathartics when combined with indifferent bases.

That, however, this explanation is not a full one they readily admit, especially as they find that quinine hydrochlorate, a well known protoplasm poison, greatly delays absorption when exhibited in traces in the solution in the gut.

The papers of O. COHNHEIM are very much to the point.

He demonstrates for the living gut membrane a condition of one sided permeability for sodium chloride somewhat of the nature of the one sided permeability found by the writer nine years ago in the living skin of the frog, and proves that this peculiarity is a function of the normal condition of the gut wall, and absent from that of the peritoneal and pleural cavities. The experiments were made with solutions of glucose in the gut, and the glucose and sodium chloride in the loop at the end of the experiment estimated.

With normal intestine only traces of sodium chloride (attributable to the *succus entericus*) are found in solutions of glucose which have remained in the gut. Addition of sodium or potassium fluoride, or especially of *liquor arsenicalis* to the glucose solution introduced into the intestine, by injury to the wall, leads to the entrance from the blood by diffusion of a large quantity of sodium chloride, which at once reduces the absorption of water from the glucose solutions, seeing that this depends largely, in the normal state, upon the partial pressure of the sodium chloride of the blood kept out of the gut by the special one sided permeability, of the gut membrane.

He thus finds the gut wall permeable to glucose and sodium chloride from the gut side, but relatively impermeable to sodium chloride from the blood side.

Strong glucose solution (10 per cent. to 15 per cent.) also injures the wall and allows the sodium chloride of the blood to enter; in fact since the power of holding back the sodium chloride of the blood is a property of the normal wall, one expects any kind of injury, chemical or mechanical, to produce the result of entrance of sodium chloride into the gut contents. An observation of GUMILEWSKI'S that the water of weak (·125 per cent. to ·25 per cent.) sodic sulphate solution is absorbed as quickly as distilled water but slower than ·25 per cent. sodium chloride, is explicable on the deleterious action of distilled water upon the gut membrane. GEZA KOVESI, in experiments on the absorption of solutions of sodium sulphate in the rabbit's gut, found sodium chloride in the solution remaining in the gut, and a glance at his figures shows that with the

stronger solutions of the sulphate (10 per cent. to 5 per cent.) the amount of sodic chloride diffused in is in excess of that found with the weaker solutions of sulphate (1·6 per cent. to 1 per cent.).

But the reduction of water absorption by the employment of protoplasm poisons is pointed out by O. COHNHEIM to be not always due to the inflow of blood salt, for with quinine and acetate of potash he noted reduction of water absorption without concomitant excess of sodium chloride in the contents of the loop.

The conclusions of certain experiments by HAMBURGER, already mentioned, dealing with the absorption of solutions by dead gut are refuted by O. COHNHEIM. HAMBURGER'S experiments were conducted without artificial circulation, and so with the supply of sodium chloride limited to that remaining in the blood vessels and tissues at the time of death.

If a circulation of ·947 per cent. solution of sodium chloride is maintained through the vessels of dead gut, or gut the wall of which has been injured by washing with glucose solution at 80° to 90° C., no absorption of introduced solution is found to occur, because the sodic chloride continues to diffuse in, as with a parchment tube, and since the glucose in the gut diffuses out more slowly than the sodium chloride of the vessels diffuses in, there is a rise of osmotic pressure in the gut and the volume of fluid in it generally increases, but never decreases. With no artificial circulation of solution of sodium chloride, the supply of sodium chloride in the gut wall is limited and a slight absorption occurs of both water and glucose.

The glucose absorptions also with dead gut and artificial circulation are, over equal periods of time, far below those obtaining in the living gut.

Thus, in experiments of 30 minutes' duration with 2·3 per cent. solution of glucose in the gut :

	Per cent. glucose absorbed.	Per cent. water absorbed.
Normal (VELLA fistula)	68·69	77·7
Dead ½ hour, and washed through vessels with ·947 per cent. solution NaCl	9·1	1·5
Heat-coagulated epithelium, and washed through vessels with ·947 per cent. solution of NaCl.	7·8	0

O. COHNHEIM concludes that two peculiarities of the gut wall must be reckoned with in a study of absorption, a power of sucking up fluid (*aufsaugende Fähigkeit*) and a one-sided permeability to sodium chloride, the two processes being separable at certain stages of poisoning, and the power of sucking up fluid being the more easily affected of the two.

Without attempting to discuss its causation, it appears to the author that one can apply this fact of one-sided permeability to plasma constituents (with special reference

to sodium chloride), to HEIDENHAIN'S experiments upon the absorption of solutions of sodium chloride and the effect of sodium fluoride thereon.

With "super-normal" solutions of salt, the salt is absorbed quicker than the water because the salt easily diffuses over into the blood, but the water uptake is difficult, depending for its initiation upon the rapid reduction of the concentration of the sodium chloride solution in the gut to blood level, and for its subsequent production, upon the absorption of the solution by virtue of the osmotic pressure of blood constituents other than sodium chloride to which the gut wall is impermeable. If by sodium fluoride the peculiar property of the membrane is removed, the diffusion of salt will be slightly slowed but will continue by virtue of the excess of the partial pressure of the salt in the introduced solution over that in the blood. On the other hand the water absorption will be greatly diminished or stopped because the plasma constituents to which the normal gut wall was impermeable now gain admittance to the solution in the gut. In other words, as HEIDENHAIN found, the water absorption will be more cut down by the poisoning with fluoride than the salt absorption.

With "sub-normal" solutions of salt, water naturally tends to be rapidly absorbed, and since diffusion in of blood salt is prevented by the property of the membrane, not till the salt solution in the gut has been concentrated (by removal of water) to blood level will salt begin to be absorbed through the osmotic pressure of plasma constituents other than salt taking it over in solution.

In a short experiment then water absorption will be noted as quicker than salt absorption.

If now the function of the membrane is destroyed by fluoride, the salt absorption will be greatly reduced or stopped by the diffusion in of the blood salt; so also in the end will be the water absorption, but since the fluid in the gut starts at a lower osmotic pressure than that of the blood, absorption of water will go on for some time. In fact the salt absorption, in a short experiment, will be cut down more than the water absorption.

In addition to the utilisation of COHNHEIM'S facts, the only change made here is that instead of supposing a special "triebkraft," the osmotic pressure of substances in the plasma, to which the gut wall is normally impermeable, is considered as a likely cause for the absorption of solutions of sodium chloride of the same concentration in this salt as the blood, and during the early stages of absorption all introduced solutions of salt must come to this level by diffusion of sodium chloride, in the case of "super-normal," and the absorption of water in the case of "sub-normal" solutions.

But is not the idea of a "triebkraft" contained in COHNHEIM'S observation? For if it be granted that no physical membrane is known or conceivable which is much more highly permeable to sodium chloride in solution in one direction than in the other, one practically admits a constant thrusting back of sodium chloride in one direction, in fact, *a mechanism.*

HÖBER'S suggestion that sodic chloride passes exclusively by the cement between

the epithelial cells cannot hold if the process is in the main a one-sided one; and, indeed, one is more inclined to think that the cement is permeable to sodium chloride in both directions, but only in slight degree, while it is a peculiarity of the living cells to be permeable in only one direction,—and the cells make up by far the greater part of the surface.

Evidence of a different character to that already adduced has also been brought forward in favour of a special act of the gut wall in absorption.

In many cases comparisons of absorptions in upper and lower districts of the small intestine have shown differences which can hardly be attributed to differences of blood supply or extent of absorbing surface.

Such comparisons should, of course, be only instituted between two loops of gut in one and the same animal, though this has not always been recognised by the investigators themselves.

TAPPEINER, studying the absorption of taurocholate, glycocholate, and cholate of soda in the intestine of the dog and cat, found that not only do different regions of the intestine absorb the bile salts in different degree, but that one and the same region may be impermeable to one salt and not to another.

The jejunum he found to possess the peculiarity of absorbing glycocholate of soda, while taurocholate and cholate are rejected, and the fat of milk was absorbed in the jejunum, while mingled taurocholate of soda was not. All three salts were absorbed in the ileum, but none of them in the duodenum. The results are apparently not due to any injury to the duodenum and jejunum, because good absorptions of water are recorded, while the bile salts were left behind.

LANNOIS and LÉPINE, comparing the absorption in different loops of gut in the same dog, found that glucose was better absorbed in the jejunum than in the ileum, but that the absorption in the duodenum was behind that in the jejunum, and sometimes even slightly less than in the ileum. Their experiments with peptone gave a similar result, but their method of estimation of peptone in the fluid removed from the gut is not free from considerable error. Oil was also found to be absorbed better in upper than in lower regions. With a solution of glucose in urine, it was found that the urea was absorbed at about the same pace in the upper and lower loops, while, as before, the glucose absorption in the lower loop was greatly inferior to that in the upper; indeed, in one case, no sugar was absorbed in a period of fifteen minutes.

LEUBUSCHER found the absorption of both salt and water from solutions of salt to be better in the jejunum than in the ileum of one and the same animal.

On the other hand, HEIDENHAIN quotes one experiment in which the absorption of water (from a 1·5 per cent. solution of sodium chloride) was considerably less in a loop 60 centims. from the pylorus, than in a loop 8 centims. from the ileo-cæcal valve in the same animal; and HÖBER and EDKINS maintain the same, but their results are from different animals.

A few other cases of comparisons of absorptions in different districts may be found scattered in the writings of others.

RÖHMANN's experiments with peptone and glucose were conducted upon different dogs with fistulous loops, and he, though inclining to the view of LANNOIS and LÉPINE, admits the uncertainty of a comparison in his results.

v. SCANZONI also observed less glucose absorption in a fistulous loop low down than in one higher up in another dog, but the difference between the distance of the loops in the two cases from the ileo-cæcal valve is not great, and the lower loop proved to be considerably the shorter of the two.

One point, the importance of which seems to have escaped the authors above mentioned, and which has forced itself upon my notice, is worthy of remark here, viz., that the epithelium of the gut tends to become detached far more easily in upper regions than in lower. RÖHMANN, it is true, remarks that the cellular elements are more easily cast off in the upper parts, but evidently does not appreciate what a serious source of error this may be in practical work.

In concluding this introduction to the paper, it is, perhaps, well to recall the fact that there is evidence of chemical action on the part of the gut wall upon certain substances known to be capable of absorption. Peptone is in some way altered in the process of its absorption, for it was not found by SALVIOLI in the blood artificially circulated through the vessels of a loop of gut from which it was being absorbed; and if, in the light of the experiments of HEIDENHAIN and SHORE, we discard the theory of HOFMEISTER that this is a function of leucocytes, we may conclude with NEUMEISTER that the epithelium of the gut is the active agent. Again, the whole story of fat absorption, whether we adopt a corpuscular or a solution theory, needs for its elucidation the assumption of action on the part of the protoplasmic structures of the gut wall; and, according to PAVY, fat is elaborated from carbohydrate in the columnar cells of the villi. [See also Note of October 19 (p. 290).]

GENERAL METHOD OF THE EXPERIMENTS.

All the experiments recorded in the following pages have been performed upon dogs, tracheotomised, and anæsthetised with chloroform and morphia, the latter drug to the extent of from 2 to 5 milligrs. per kilo. of body weight, and unless specially stated to the contrary, the animals had fasted for 24 hours previous to the experiment.

The method introduced by LEUBUSCHER of using simultaneously two loops of gut, experimental and control, has been followed throughout, and in all cases the loops of gut have lain, during the actual experimental period, outside the abdominal cavity with the mesenteries free of torsion, and covered with flannels wrung out in warm water. Only one experiment was performed upon each animal, in order to avoid error from injury to epithelium, differences in vascularity, or other possible untoward effects.

For special purposes the hydrostatic pressure within the loops of gut was measured during the experiment by small manometers tied water-tight through a "button-

hole" in the mucous membrane, but it may be remarked that if two loops of gut of equal length are selected, and the same volume of the experimental fluid filled into each, the difference of hydrostatic pressure in the loops is so small that the manometric procedure may be dispensed with except in special cases. Peristaltic contraction of the exposed loops of gut was the exception under the circumstances, and if evidently more marked in one loop than the other, the result of the experiment was only accepted when it tallied with others of a similar nature in which peristalsis was absent.

The loops of gut were provided with glass cannulæ at each end (the free end of each cannula being supplied with a short rubber tube and clip), were laved with ·9 per cent. salt solution at body temperature to remove *débris* of food and worms, and, as a rule, washed with the solution to be absorbed immediately before the commencement of the experiment.

In order that the double loop method may give reliable results certain precautions are necessary, viz., (1) the length of the loops must be measured with great care; (2) the circulation in the one must be as good as in the other; and (3) the two loops must be selected in continuity from the middle region of the ileum of a fair-sized dog.

The measurement of two loops of gut of equal length is merely a matter of practice and skill, but the maintenance of equality of circulation depends upon absence of torsion in the mesentery, in the main. If the loops are replaced in the abdomen for the experimental period, however carefully they have been measured, one is liable to get inequalities in absorption, and it is only by careful arrangement of the loops on the warm cloths lying on the abdomen, and attention to the mesentery at its point of exit from the abdominal wound, that equality of absorption is at command.

How necessary the third point is will be evident from the results given on p. 283 of comparisons of absorptions in the upper and lower regions of the ileum.

At the end of an experimental period the contents of the loops were emptied into measuring vessels capable of being read to half a cubic centimetre, and when solutions of sugar or peptone were used the loops were thoroughly washed with distilled water, the washings boiled down to small volume, and added to the fluid directly recovered, before proceeding to quantitative analysis of the substance in solution.

The solutions were introduced into the loops at body temperature from vessels jacketed with warm water.

The methods of chemical treatment will be found in the Appendix on p. 291, along with other practical details here out of place.

That the above method of procedure is reliable is, I think, proved by the comparison of absorptions of serum, peptone, and sugar, in two normal loops from the mid-region of the ileum quoted in Tables I., II., and III.

TABLE I.—Comparison of Absorptions of Dog's Own Serum by Two Normal Loops of Ileum.

Number of experiment.	Weight of dog in kilogrammes.	Duration of experiment in minutes.	Length of loops of gut in centims.	Distance of lower loop from ileo-cæcal valve in centims.	Volume of own serum introduced into each loop in cub. centims.	Absorptions.					
						Upper loop.			Lower loop.		
						Water.	Organic solids.	Salts.	Water.	Organic solids.	Salts.
I.	19	40	80	75	50	23 cub. centims. = 46 per cent.	·6470 grm. = 19·31 per cent.	·2223 grm. = 47·80 per cent.	21·5 cub. centims. = 43 per cent.	·5781 grm. = 17·25 per cent.	·2074 grm. = 44·60 per cent.
II.	26	60	80	100	50	26 cub. centims. = 52 per cent.	1·2269 grm. = 34·63 per cent.	·2505 grm. = 55·30 per cent.	26 cub. centims. = 52 per cent.	1·2860 grm. = 36·30 per cent.	·2538 grm. = 56·02 per cent.
III.	21	30	80	100	40	21 cub. centims. = 52·50 per cent.	·5440 grm. = 17·69 per cent.	·2104 grm. = 54·67 per cent.	22 cub. centims. = 55·0 per cent.	·5608 grm. = 18·23 per cent.	·2118 grm. = 55·04 per cent.
IV.	18	30	80	100	50	23 cub. centims. = 46·0 per cent.	·6818 grm. = 20·62 per cent.	·2223 grm. = 46·40 per cent.	24 cub. centims. = 48·0 per cent.	·7889 grm. = 23·86 per cent.	·2349 grm. = 49·04 per cent.

NOTE.—The intra-intestinal hydrostatic pressure was measured in Experiments III. and IV.

In Experiment III., upper loop pressure 5 to 11 millims. of Hg,
lower „ „ 3 „ 12 „ „

In Experiment IV., upper „ „ 5 „ 7 „ „
lower „ „ 6 „ 7 „ „

For method of analysis see Appendix, p. 291.

TABLE II.—Comparison of Absorptions of Solution of Commercial (GRÜBLER'S) Peptone by Two Normal Loops of Ileum.

Number of experiment.	Weight of dog in kilogrammes.	Duration of experiment in minutes.	Length of loops of gut in centims.	Distance of lower loop from ileo-cæcal valve in centims.	Volume of 2 per cent. solution of peptone introduced into each loop in cub. centims.	Absorptions.			
						Upper loop.		Lower loop.	
						Water.	Peptone.	Water.	Peptone.
I.	14	15	30	75	30	19·5 cub. centims. = 65·00 per cent.	·425 grm. = 70·83 per cent.	21·0 cub. centims. = 70·00 per cent.	·455 grm. = 75·83 per cent.
II.	16	15	30	100	36	26·00 cub. centims. = 72·23 per cent.	·462 grm. = 64·16 per cent.	25·00 cub. centims. = 69·44 per cent.	·436 grm. = 60·55 per cent.
III.	18	15	30	150	30	20·50 cub. centims. = 68·34 per cent.	·425 grm. = 70·83 per cent.	19·50 cub. centims. = 65·00 per cent.	·440 grm. = 73·34 per cent.
IV.	11·5	15	30	100	30	17·50 cub. centims. = 58·34 per cent.	·321 grm. = 53·50 per cent.	18·50 cub. centims. = 61·67 per cent.	·304 grm. = 50·67 per cent.
V.	9·5	15	30	100	30	25·00 cub. centims. = 83·34 per cent.	·408 grm. = 68·00 per cent.	25·00 cub. centims. = 83·34 per cent.	·404 grm. = 67·34 per cent.

For methods of analysis see Appendix, p. 293.

TABLE III.—Comparison of Absorptions of Solution of Glucose by Two Normal Loops of Ileum.

Number of experiment.	Weight of dog in kilogrammes.	Duration of experiment in minutes.	Length of loops of gut in centims.	Distance of lower loop from ileo-cæcal valve in centims.	Volume of 2 per cent. solution of glucose introduced into each loop in cub. centims.	Absorptions.			
						Upper loop.		Lower loop.	
						Water.	Glucose.	Water.	Glucose.
I.	18	30	38	75	30	17·0 cub. centims. = 56·67 per cent.	·2537 grm. = 42·28 per cent.	18·0 cub. centims. = 60·00 per cent.	·2703 grm. = 45·05 per cent.
II.	16·5	30	50	75	40	20·0 cub. centims. = 50·00 per cent.	·3964 grm. = 49·55 per cent.	18·5 cub. centims. = 46·25 per cent.	·3886 grm. = 48·57 per cent.
III.	20	15	40	100	30	24·0 cub. centims. = 80·00 per cent.	·3162 grm. = 52·70 per cent.	24·5 cub. centims. = 81·67 per cent.	·3300 grm. = 55·00 per cent.
IV.	15	15	30	75	30	19·0 cub. centims. = 63·34 per cent.	·2480 grm. = 41·34 per cent.	18·0 cub. centims. = 60·00 per cent.	·2454 grm. = 40·90 per cent.

NOTE.—In Experiments I. and II. the glucose was dissolved in a ·6 per cent. solution of common salt. In Experiments III. and IV. it was dissolved in distilled water.

For methods of analysis see Appendix, p. 293.

THE ABSORPTION OF SERUM BY THE ILEUM.

By restricting experiments to dogs upwards of 15 kilos. in weight, it is possible to obtain sufficient blood for subsequent preparation of serum by the centrifugal machine, without inducing such a degree of anæmia that the integrity of the intestinal epithelium or the life of the animal are endangered.

By such procedure one approaches as nearly as experimentally feasable the condition of identity of the solution on either side of the intestinal membrane, and excludes the osmotic factor far more completely than when another animal's serum is used for experiment, as was done by VOIT and BAUER and by HEIDENHAIN.

Subject to variations called for by the condition of the animal, the rule has been to take about 400 cub. centims. of blood from dogs weighing from 15 to 20 kilos., 500 cub. centims. from dogs of 20 to 25 kilos., while 600 cub. centims. has been

drawn from dogs of 30 kilos. and upwards without danger. The serum, warmed to 40° C., was usually ready for introduction into the gut within an hour after bleeding the dog from the carotid artery.

(a) *Absorption of Serum against Hydrostatic Pressure. Exclusion of Filtration into Capillaries of Villi and Lacteals.*

The attempt by HAMBURGER, already noted in the introduction, to revive the filtration theory of absorption of LIEBERKÜHN, BRÜCKE, and VOIT and BAUER, a theory disregarded by HEIDENHAIN in his experiments upon the absorption of serum in the intestine, compelled me to measure the hydrostatic pressure simultaneously in the gut lumen and in a radical of a mesenteric vein, during an absorption of serum, —an experimental precaution, so far as I am aware, previously neglected.

Readings were simultaneously taken of a manometer communicating with the interior of a loop of gut charged with the animal's own serum, and of another manometer (filled with magnesium sulphate solution of known density), tied into a mesenteric vein radical, proceeding from a neighbouring loop of gut filled with normal saline solution. The venous radical selected was as near the border of the gut as practicable for introduction of a cannula.

As will be evident from the experiments now quoted, active absorption of serum takes place when the hydrostatic pressure in the gut is well below that in a radical of a mesenteric vein, and, therefore, far below that in the capillaries of the villi.

EXPERIMENT I.—Dog, 17·5 kilos. 80 centims. Loop of Ileum. Duration of experiment, 1 hour.

	Organic solids.	Salts.
	grms.	grm.
Introduced into gut 50 cub. centims. of own serum, holding	3·3500	·4500
Recovered from gut 22 cub. centims. of serum, holding.	2·3474	·1870

ABSORBED DURING THE HOUR.

Water	28·00 cub. centims., *i.e.*,	56·00 per cent.
Organic solids.	1·0026 grm., . . „	29·92 „
Salts	·2630 „ . . „	58·45 „

PRESSURES IN MILLIMETRES OF MERCURY.

Time.	Mesenteric vein radical.	Gut lumen.
12.0 start		
12.5	18·4	5·0
12.10	16·1	5·0
12.20	16·1	6·0
12.30	15·0	5·5
12.40	15·4	4·5
12.50	13·5	4·0
1.0 stop		

EXPERIMENT II.—Dog, 20 kilos. 80 centims. Loop of Ileum. Duration of experiment, 1 hour.

	Organic solids.	Salts.
	grms.	grm.
Introduced into gut 50 cub. centims. of own serum, holding	3·4350	·4550
Recovered from gut 18·5 cub. centims. of serum, holding	2·0646	·1628

ABSORBED DURING THE HOUR.

Water . . . . . 31·5 cub. centims., *i.e.*, 63·00 per cent.
Organic solids . . . . . 1·3704 grm., . . „ 39·89 „
Salts . . . . . ·2922 „ . . „ 64·22 „

PRESSURES IN MILLIMETRES OF MERCURY.

Time.	Mesenteric vein radical.	Gut lumen.
12.5 start		
12.10	10·7	2·0
12.20	11·5	2·0
12.30	11·1	2·0
12.40	11·5	3·0
12.50	11·4	3·0
1.0	Clot	3·0
1.5 stop		

If the serum passes to the blood in the capillaries of the villi, it is evident that filtration is not here the cause of its motion.

The supposition at once arises that the explanation of the absorption under these circumstances is filtration into the lacteals of the villi.

In an animal, with the lacteals of the mesentery whitened by fat feeding, it is an

easy matter to ligature these vessels close to the gut border, and so make the lacteal plexus of the submucosa a closed system, if the loop of gut is ligatured round a cannula at each end.

If the ligature of the mesenteric lacteals is carried out some time before the absorption experiment, the pressure in the villus parenchyma and in the closed lymphatic system of the loop must at the time of starting the experimental absorption be but little below the capillary blood pressure, and during the whole experiment will certainly not tend to fall.

BRÜCKE'S "villus pump," if such a mechanism really acts during absorption, will be practically crippled, and unable to reduce the pressure in the central lacteal below the level of the pressure within the loop of gut.

Nevertheless, as shown in the two following experiments, the absorption of serum still occurs when the mesenteric lacteals are closed by ligature near the gut border. Examples are quoted in Experiments III. and IV.

EXPERIMENT III.—Dog, 22 kilos. 80 centims. Loop of Ileum. Duration of experiment, 1 hour. Lacteals of mesentery ligatured near border of gut 45 minutes before commencement of experiment.

	Organic solids.	Salts.
	grms.	grm.
Introduced into gut 50 cub. centims. of own serum, holding	3·6450	·4500
Recovered from gut 25 cub. centims. of serum, holding	2·6080	·2220

ABSORBED DURING THE HOUR.

Water	25·00 cub. centims., *i.e.*,	50·00	per cent.
Organic solids	1·0370 grm., . . „	28·45	„
Salts	·2280 „ . . „	50·67	„

PRESSURES IN MILLIMETRES OF MERCURY.

Time.	Mesenteric vein radical.	Gut lumen.
12.20 start		
12.25	15·4	3·0
12.35	16·9	2·5
12.45	17·3	2·5
12.55	21·5	2·5
1.5	16·9	2·0
1.15	17·3	2·0
1.20 stop		

EXPERIMENT IV.—Dog, 20 kilos. 80 centims. Loop of Ileum. Duration of experiment, 1 hour. Lacteals of mesentery ligatured near border of gut 35 minutes before commencement of experiment.

	Organic solids.	Salts.
	grms.	g m.
Introduced into gut 50 cub. centims. of own serum, holding	3·6830	·4570
Recovered from gut 22·5 cub. centims. of serum, holding	2·6307	·2043

ABSORBED DURING THE HOUR.

Water	27·5 cub. centims., *i.e.*,	55·00	per cent.
Organic solids	1·0523 grm., . . „	28·57	„
Salts	·2527 „ . . „	55·29	„

PRESSURES IN MILLIMETRES OF MERCURY.

Time.	Mesenteric vein radical.	Gut lumen.
12.20 start		
12.23	18·4	1·5
12.30	17·7–18·4	1·5
12.40	19·2	4·0
12.50	21·9	3·5
1.0	20·8	3·5
1.10	18·4	3·0
1.15	16·9	3·0
1.20 stop		

Furthermore, a comparison of the absorption of serum in a loop with tied lacteals with that in one with lacteals free, shows no diminution in uptake on the side with ligatured lacteals.

Indeed, in Experiments V. and VI. now quoted, the absorption is a little greater on the side with ligatured lacteals, probably as a result of rather greater blood supply from the handling involved in ligaturing the vessels.

EXPERIMENT V.—Dog, 20 kilos. Two 70 centims. Loops of Ileum. Duration of experiment, $\frac{1}{2}$ hour. Lacteals of upper loop tied 30 minutes before commencement of experiment. Lower loop normal.

	Organic solids.	Salts.
	grms.	grm.
Introduced 40 cub. centims. of own serum, holding	2·4520	·3640
Recovered: Normal loop, 22 cub. centims.	1·8298	·1942
„ Loop with lacteals tied, 20 cub. centims.	1·7668	·1792

ABSORBED IN ½ HOUR.

	Normal loop.	Loop with lacteals tied.
Water . . .	18·00 cub. centims., *i.e.*, 45·00 per cent.	20·00 cub. centims., *i.e.*, 50·00 per cent.
Organic solids .	·6222 grm., . . „ 25·37 „	·6852 grm., . . „ 27·94 „
Salts	·1698 „ . . „ 46·64 „	·1848 „ . . „ 50·77 „

PRESSURES IN MILLIMETRES OF HG.

Time.	Normal loop.	Loop with lacteals tied.
11.36 start		
11.40	7	7
11.45	5	8
11.50	7	8
11.55	7	8
12·0	7	6
12.6 stop		

NOTE.—The loop with tied lacteals was slightly hyperæmic (handling in tying lacteals?).

EXPERIMENT VI.—Dog, 22 kilos. Two 60 centims. Loops of Ileum. Duration of experiment, ½ hour. Lacteals of lower loop tied 1 hour before commencement of experiment. Upper loop normal.

	Organic solids.	Salts.
	grms.	grm.
Introduced 40 cub. centims. of own serum, holding	2·7996	·3684
Recovered: Normal loop, 34 cub. centims. serum, holding	2·5409	·3117
„ Loop with tied lacteals, 33 cub. centims. serum, holding .	2·4425	·3032

ABSORBED IN ½ HOUR.

	Normal loop.	Loop with tied lacteals.
Water . . .	6·00 cub. centims., *i.e.*, 15·00 per cent.	7·00 cub. centims., *i.e.*, 17·50 per cent.
Organic solids .	·2587 grm., . . „ 9·24 „	·3571 grm., . . „ 12·75 „
Salts	·0567 „ . . „ 15·39 „	·0652 „ . . „ 17·70 „

PRESSURES IN MILLIMETRES OF MERCURY.

Time.	Normal loop.	Loop with tied lacteals.
11.30 start		
11.32	6	5
11.40	6	5
11.45	6	5
11.50	5	5
11.55	4	5
11.58	5	5
12.0 stop		

Finally, as will be shown later, removal of the cylinder epithelium from the villi, a procedure which by thinning the membrane is favourable to filtration, whether into lacteal or capillary, is found to be the most serious experimental hindrance to the absorption of serum.

(RANKE, thirty years back, demonstrated that removal of the gut epithelium facilitates the filtration of salt solution through the wall of fresh gut from the ox.)

(b) *Exclusion of Osmosis.*

If, then, it be concluded that filtration is not the explanation of the absorption of serum, before going further, it must be absolutely proved that osmosis is not concerned.

In my experimental experience it has often been noted that the lowering of freezing point of the serum of the blood of the dog at the end of the experiment is a little in excess of that of the serum of the blood first drawn and used for the absorption experiment. This is, however, by no means always the case, *e.g.*, in Experiment III. just quoted, where a good absorption occurred, the freezing point of the serum of the dog at the end of the experiment was — ·590° C., and that of the serum introduced into the intestine — ·615° C., and in Experiment IV. the figures were practically identical, viz., — ·603° C. for the serum of the dog at the end of the experiment, and — ·600° C. for the serum introduced into the gut.

The thought occurs that possibly the partial osmotic pressure of the sodium chloride of the circulating plasma might, by virtue of the impermeability of the gut wall to this salt in the direction from the blood to the gut lumen, be made responsible for the absorption.

This hypothesis was therefore put to the test, but, as seen in Experiment VII., it is found wanting.

EXPERIMENT VII.—Dog, 22 kilos. 80 centims. Loop of Ileum. Duration of experiment, ½ hour.

	Organic solids.	Salts.
	grms.	grm.
Introduced 50 cub. centims. of own serum, holding	3·5145	·4805
Recovered 27 cub. centims. of serum, holding	2·5858	·2465

ABSORBED DURING THE ½ HOUR.

Water . . . . . 23 cub. centims., *i.e.*, 46·00 per cent.
Organic solids . . . . . ·9287 grm., . „ 26·42 „
Salts . . . . . ·2340 „ . „ 48·70 „

LOWERINGS OF FREEZING POINT.

Introduced serum.	Serum removed from gut.	Serum of dog at end of experiment.
$\Delta = -$ ·600	$\Delta = -$ ·575	$\Delta = -$ ·610

10 cub. centims. of oxalate (·1 per cent. potass. oxalate) plasma from dog at end of experiment, and also 10 cub. centims. of introduced serum, dialysed (GÜRBER'S method) 24 hours (with shaking) into 40 cub. centims. distilled water.

N.B.—The dialysed oxalate plasma clotted on addition of calcic chloride.

Sodic chloride estimation by VOLHARD, method in dialysate gave,

NaCl of plasma of dog at end of experiment.	NaCl of introduced serum.
·70 per cent.	·70 per cent.

Alkalinity of plasma at end of experiment and of introduced serum also identical.

It was found that 55·55 per cent. of the sodic chloride of the serum introduced had been absorbed.

It is evident that since the partial osmotic pressure of sodic chloride and of alkalis is identical in the plasma of the dog at the end of the experiment with that of the serum introduced into the loop of gut, the absorption of serum noted was not due to any difference in osmotic pressure of these constituents on the two sides of the membrane.

It will be remembered also in this connection that HEIDENHAIN found that inspissated serum was absorbed.

I believe, therefore, that both osmosis and filtration may be excluded in any theory of the absorption by an animal of its own serum placed in a loop of its intestine.

Finally, in the following experiment (Experiment VIII.) it is shown that an animal can absorb its own blood plasma (prepared by oxalate of potassium).

Slight clotting occurs, since as has been shown by FRITZ VOIT, considerable quantities of lime salts are present in the *succus entericus*.

EXPERIMENT VIII.—Absorption of oxalate plasma. Dog, 16·5 kilos. 80 centims. Loop of Ileum. Duration of experiment, 40 minutes. Introduced 50 cub. centims. of ·1 per cent. potassium oxalate plasma prepared from animal's own blood.

	Organic solids.	Salts.
	grms.	grm.
Introduced 50 cub. centims. oxalate plasma, holding	2·7295	·4905
Recovered 34·5 cub. centims. plasma, holding	2·1542	·3229

ABSORBED IN 40 MINUTES.

Water	15·5 cub. centims., *i.e.*,	31·00 per cent.
Organic solids	·5753 grm., . .	„ 21·07 „
Salts	·1676 „ . .	„ 34·16 „

A partial clotting of the plasma in the gut had occurred where it was in contact with the gut wall. The fluid portion clotted firmly on addition of calcium chloride.

No evidence of epithelial loss or ecchymosis.

(c) *Exclusion of Adsorption.*

In searching for other physical causes one thinks first of *adsorption*.

It is possible that what is read as an absorption is a simple soakage, a sort of "dyeing" of the gut membrane with the serum, for we have no means of identification upon the blood side of the membrane of the serum supposed to be absorbed.

VOIT and BAUER have already considered this question, and found no *adsorption* of egg albumen during a 2 hours' sojourn of a 12 per cent. solution in a dead loop of cat's intestine.

Against *adsorption* as an explanation of the absorption of its own serum by an animal, I would further advance the following:

We are using for experiment the solution which has been flowing through the gut wall ever since it existed, and the histological elements must be at the commencement of an experiment soaked to the highest degree possible with those constituents which in their normal condition are capable of uptake, and no reason is evident why they should suddenly begin to take up more. Again, a preliminary washing of a loop with serum does not affect the final result.

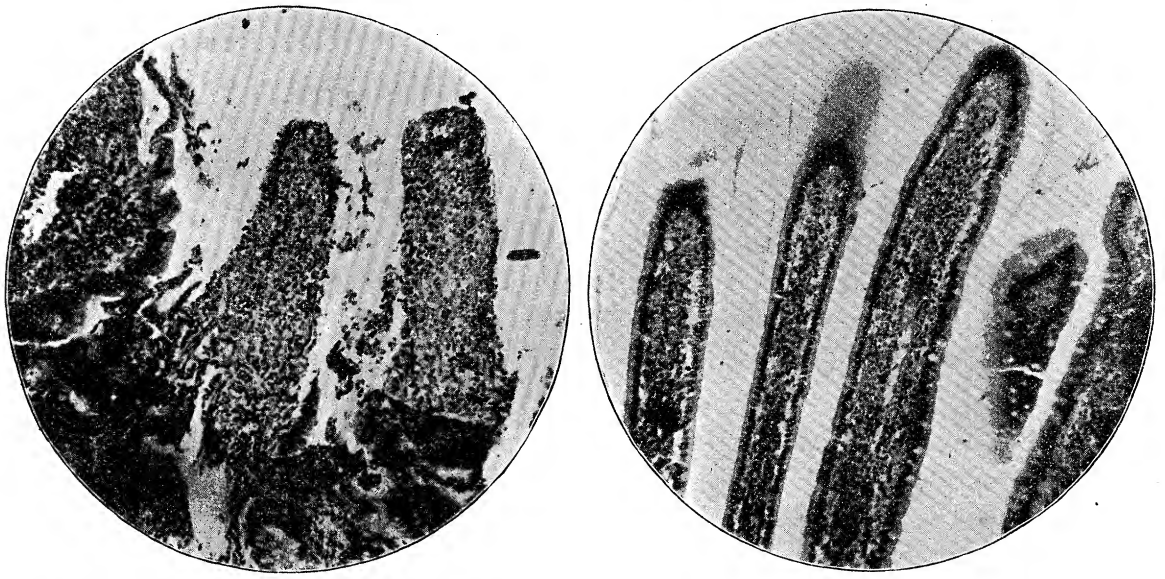
It will also be remembered that VOIT and BAUER, and also EICHHORST, in many cases estimated the absorption of albumen solutions, in the large gut by the excretion of urea,—positive evidence of the passage of the albumen through into the blood.

(d) *Improbability of Electro-osmotic Explanation.*

If *adsorption* is rejected, there remains, so far as my knowledge goes, only electro-osmose. ROSENTHAL demonstrated an ingoing electrical current in the gut mucosa of the rabbit, and if the filtration porosity in the direction from the superficial to the deeper layer of the mucosa exceeded that in the opposite direction, it is possible to have a movement of fluid in the desired direction by the electric current.

But against this hypothesis we have the fact that purely secretory membranes, as demonstrated by ENGELMANN, HERMANN, BIEDERMANN, and others, exhibit electrical currents in the same direction as those in absorbing membranes, and a special excess of porosity in the direction of the secreted fluid would have to be here assumed.

By the rejection of osmosis, filtration, *adsorption*, and electro-osmose as explanations of the absorption of serum, we are reduced to considering it as due to some special action of the epithelial cells, as did HEIDENHAIN, though, I believe, upon insufficient data.



Epithelium of villi removed by previous anæmia. Normal control from the same animal.

(The experiment from which these are taken was Experiment VI. in Table XII., p. 277.)

If one is driven by force of negatives to the use of the expression "cell action," it must be clearly understood that the use of such a term in no way connotes the supposition that the forms of energy utilised in the cell mechanism are other than those known in the physical world. The hypothesis of a special form of energy peculiar to things alive is perfectly rational, but superfluous until, by elimination, the know forms of energy are proved to be insufficient. Such proof is in the present state of ignorance of cell mechanics impossible.

EFFECTS OF REMOVAL OF AND INJURY TO EPITHELIUM.

The truth of the hypothesis that a mechanism resident in the epithelial cells is the

cause of the motion of serum, placed in the gut, over into the blood, is capable of test by the simple expedient of removal of the epithelium, and comparison of the result on absorption with that of an experiment with a normal epithelium-clad loop in the same animal.

(1) *Temporary Anæmia.*

The epithelium of the intestine is very loosely attached, especially towards the tips of the villi. The method of regeneration, involving a sliding of the cells on the basement membrane, as demonstrated by BIZZOZERO, HEIDENHAIN, CLOETTA, SCHAFFER, and others, the "rice water" stools of cholera, and the early period after death at which the cells separate from the basement membrane (NOTHNAGEL) all point to this, so that in experimental work with the intestine the greatest care in manipulation is necessary to ensure that the epithelium remains intact. A temporary anæmia of a loop of gut by clamping the arteries of the mesentery will ensure very considerable removal of the cylinder epithelium, as is evident from the photographs on the preceding page.

Clamping the mesenteric vessels for a period of from a quarter to half-an-hour is sufficient to ensure loss of epithelium, and upon restitution of the circulation during the experimental absorption, the circulation in the previously anæmic loop is, as a rule, superior to that in the normal loop.

The following two experiments (Experiments IX. and X.) demonstrate the effect of removal of epithelium by previous anæmia (without the use of any drugs), upon the absorption of serum.

EXPERIMENT IX.—Dog, 16 kilos. Two 80 centims. Loops of Ileum. Duration of experiment, $\frac{1}{2}$ hour. Mesenteric vessels of one loop clamped for 20 minutes previous to experiment. Great detachment of epithelium.

	Organic solids.	Salts.
	grms.	grm.
Introduced into each loop 50 cub. centims. of own serum, holding . .	3·2465	·4735
Recovered: Normal loop, 35 cub. centims. of serum, holding	2·4847	·3188
„ Previously anæmic loop, 48 cub. centims. of serum, holding	2·9573	·4507

ABSORBED IN $\frac{1}{2}$ HOUR.

	Normal loop.	Previously anæmic loop.
Water . . .	15·00 cub. centims., *i.e.*, 30·00 per cent.	2 cub. centims., *i.e.*, 4·00 per cent.
Organic solids .	·7618 grm., . . „ 23·46 „	·2892 grm., . „ 8·90 „
Salts	·1547 „ . . . „ 32·67 „	·0228 „ . . „ 4·81 „

HYDROSTATIC PRESSURES.

Normal loop . . . . . 7 to 10 millims. of Hg.
Previously anæmic loop . . . 7 to 10 „ „

N.B.—During the period of absorption the previously anæmic loop was hyperæmic.

EXPERIMENT X.—Dog, 16 kilos. Two 80 centims. Loops of Ileum. Duration of experiment, ½ hour. Mesenteric vessels of one loop clamped for 15 minutes before experiment. Great detachment of epithelium.

	Organic solids.	Salts.
	grms.	grm.
Introduced into each loop 35 cub. centims. of own serum, holding . .	2·0888	·3262
Recovered: Normal loop, 18 cub. centims. serum, holding.	1·3225	·1661
„ Previously anæmic loop, 30 cub. centims. serum, holding .	1·6905	·2835

ABSORBED IN ½ HOUR.

	Normal loop.	Previously anæmic loop.
Water . . .	17·00 cub. centims., *i.e.*, 48·57 per cent.	5·00 cub. centims., *i.e.*, 14·28 per cent.
Organic solids .	·7663 grm., . . „ 36·68 „	·3983 grm., . . „ 19·07 „
Salts	·1601 „ . . „ 49·08 „	·0427 „ . . „ 13·09 „

HYDROSTATIC PRESSURES.

Normal loop . . . . . 5 to 7 millims. of Hg.
Previously anæmic loop . . . 5 to 7 „ „

N.B.—During the period of absorption the previously anæmic loop was hyperæmic.

In these experiments, in each case the hydrostatic pressure was the same in the control as in the experimental loop, yet though, by the removal of the epithelium, the conditions for filtration must have been superior on the side where the membrane had been thinned by the loss of cells, it is on this side that the absorption is defective.

Since the attachment of the gut epithelium is so delicate, and evidently intimately associated with the physiological condition of the cells themselves, it is evident that any procedure tending to injury of the cells, will also tend to denudation of the villi.

(2) *Distilled Water.*

Distilled water acts very deleteriously on protoplasm, and the mere washing out of a loop of gut with distilled water, especially in an animal which has been previously bled, is very effective.

Instances (Experiments XI. and XII.) are now given of the absorption of serum in a loop of gut washed with distilled water contrasted with that in a loop washed with normal saline solution in the same animal.

EXPERIMENT XI.—Dog, 16 kilos. Two 80 centims. Loops of Ileum. Duration of experiment, 1 hour. One loop washed with distilled water, the other with ·9 per cent. solution of sodic chloride. Great loss of epithelium in the water washed loop. Slight loss in the control loop.

	Organic solids.	Salts.
	grms.	grm.
Introduced into each loop 50 cub. centims. own serum, holding . . .	3·1650	·4700
Recovered: Normal loop, 39 cub. centims. serum, holding	2·7417	·3588
„ Water washed loop, 47 cub. centims. serum, holding . .	2·9751	·4512

ABSORBED IN 1 HOUR.

	Normal loop.	Water washed loop.
Water . . .	11 cub. centims., *i.e.*, 22·00 per cent.	3 cub. centims., *i.e.*, 6·00 per cent.
Organic solids .	·4233 grm., . „ 13·37 „	·1899 grm., . „ 6·00 „
Salts	·1112 „ . . „ 23·66 „	·0188 „ . . „ 4·00 „

HYDROSTATIC PRESSURES.

Normal loop . . . . . 6 to 8 millims. of Hg.
Water washed loop . . . . . 6 to 8 „ „

EXPERIMENT XII.—Dog, 26 kilos. Two 80 centims. Loops of Ileum. Duration of experiment, 20 minutes. One loop washed with distilled water, the other with ·9 per cent. sodic chloride solution. Detachment of epithelium in water washed loop not great. The serum used in this experiment was diluted with an equal volume of ·9 per cent. solution of NaCl.

	Organic solids.	Salts.
	grms.	grm.
Introduced into each loop 50 cub. centims. diluted serum, holding . .	1·7725	·4825
Recovered: Normal loop, 28·5 cub. centims. serum, holding	1·2441	·2778
„ Water washed loop, 37·5 cub. centims. serum, holding . .	1·5833	·3667

ABSORBED IN 20 MINUTES.

	Normal loop.	Water washed loop.
Water . . .	21·5 cub. centims., *i.e.*, 43·00 per cent.	12·5 cub. centims., *i.e.*, 25·00 per cent.
Organic solids .	·5281 grm., . . „ 29·81 „	·1892 grm., . . „ 10·67 „
Salts	·2047 „ . . „ 42·42 „	·1158 „ . . „ 24·00 „

HYDROSTATIC PRESSURES.

Normal loop . . . . . 3·5 to 5 millims. of Hg.
Water washed loop . . . . . 4 to 5 „ „

(3) *Sodium Fluoride.*

Finally, in this connection, the washing out of a loop of intestine with a weak solution of sodium fluoride (·1 per cent.) previous to the experimental absorption, may bring the absorption to an absolute standstill, for not only is there considerable detachment of the epithelial cells, but any cells remaining *in situ* are more or less poisoned.

An example of this is now quoted in Experiment XIII.

EXPERIMENT XIII.—Dog, 23·5 kilos. Two 80 centims. Loops of Ileum. Duration, 1 hour. One loop washed with ·8415 per cent. solution of sodic chloride, holding ·1 per cent. of sodic fluoride, the other with ·9804 per cent. solution of sodic chloride. Lowering of freezing point of each wash = — ·590° C.

	Organic solids.	Salts.
	grms.	grm.
Introduced into each loop 50 cub. centims. of own serum, holding . .	3·6050	·4550
Recovered: Normal loop, 20 cub. centims. serum, holding	1·8740	·1720
„ Fluoride washed loop, 50 cub. centims. serum, holding . .	3·3700	·4700

ABSORBED IN 1 HOUR.

	Normal loop.	Fluoride washed loop.
Water. . . .	30·00 cub. centims., *i.e.*, 60·00 per cent.	0·00 cub. centim., *i.e.*, 0·00 per cent.
Organic solids .	1·7310 grm., . . „ 48·01 „	·235 grm., . . „ 6·52 „
Salts	·2830 „ . . „ 62·19 „	Added, ·015 „ . . . „ 3·30 „

HYDROSTATIC PRESSURES.

Normal loop . . . . . 7 to 11 millims. of Hg.
Fluoride washed loop . . . . 9 to 12 „ „

LOWERINGS OF FREEZING POINT.

Introduced serum.	Removed from fluoride loop.	Removed from normal loop.	Serum of dog at end of experiment.
– ·600° C.	– ·630° C.	– ·560° C.	– ·640° C.

Here the expected physical phenomenon of complete absence of absorption of water is fully realised on the side where the epithelium is injured, at a time when in the

normal loop in the same animal some 60 per cent. of the water and salts of the introduced serum is taken up. The hydrostatic pressure, too, it may be noted, slightly favours filtration on the side on which no water is absorbed during the hour.

The result is even more certain if in addition to washing the loop with weak sodic fluoride solution a small quantity of the salt is added to the serum introduced into the poisoned loop.

The following experiment (XIV.) is an instance.

EXPERIMENT XIV.—Dog, 40 kilos. Two 80 centims. Loops of Ileum. Duration of experiment, 1 hour. Washes as in last experiment, but in addition ·08 per cent. of sodic fluoride was present in serum in poisoned loop.

	Organic solids.	Salts.
	grms.	grm.
Introduced into each loop 50 cub. centims. of own serum, holding . .	3·8160	·4590
Recovered: Normal loop, 25 cub. centims. serum, holding	2·6065	·2160
„ Fluoride loop, 50 cub. centims. serum, holding	3·5395	·4555

ABSORBED IN 1 HOUR

	Normal loop.	Fluoride loop.
Water. . . .	25·00 cub. centims., *i.e.*, 50·00 per cent.	0·00 cub. centims., *i.e.*, 0·00 per cent.
Organic solids .	1·2095 grm., . . „ 31·69 „	·2765 grm., . . „ 7·24 „
Salts	·2430 „ . . „ 52·94 „	·0035 „ . . „ ·76 „ *

LOWERINGS OF FREEZING POINT.

Introduced normal serum.	Introduced fluoride serum.	Removed normal serum.	Removed fluoride serum.	Serum of dog at end of experiment.
– ·600° C.	– ·655° C.	– ·560° C.	– ·605° C.	– ·605° C.

HYDROSTATIC PRESSURES.

Normal loop . . . . . 7 to 10 millims. of Hg.
Fluoride loop . . . . . 6 to 10 „ „

N.B.—Pups in uterus of this dog. Lowering of freezing point of pups' serum – ·710° C. Amniotic fluid – ·565° C.

The added sodium fluoride appears to have been absorbed by the end of the hour

* Calculated on the serum salts. If added sodic fluoride is reckoned, absorption of ·0335 grm. salts = 6·71 per cent.

in this experiment, for the determination of the lowerings of freezing point show that the serum withdrawn from the previously poisoned loop had the same freezing point as the blood of the animal, while the "fluoride serum" introduced naturally had a considerably greater lowering of freezing point.

Since in many of the experiments with sodium fluoride, quotation of which would too greatly increase the bulk of this communication, the hydrostatic pressure in the fluoride poisoned loop was often noted to be in excess of that in the normal loop, probably on account of the fact that the fluoride causes a certain amount of tonic contraction of the musculature, it was necessary to perform an experiment with a higher hydrostatic pressure in the normal loop, maintained artificially throughout the period of absorption, in order to see whether the absence of absorption in a fluoride loop was in *any way* associated with the higher pressure. Such an experiment is here reproduced (Experiment XV.), and it is evident that the result is the same as when the pressure is higher in the fluoride loop.

EXPERIMENT XV.—Dog, 17 kilos. Two 80 centims. Loops of Ileum. Duration of experiment, 1 hour. Washes as in last experiment, but in addition ·053 per cent. of sodic fluoride was present in the serum in poisoned loop.

	Organic solids.	Salts.
	grms.	grm.
Introduced into each loop 50 cub. centims. of own serum, holding . .	3·6765	·4585
Recovered: Normal loop, 30 cub. centims. serum, holding.	2·7210	·2640
,, Fluoride loop, 47 cub. centims. serum, holding	3·4780	·4230

ABSORBED IN 1 HOUR.

	Normal loop.	Fluoride loop.
Water. . . .	20·00 cub. centims., *i.e.*, 40·00 per cent.	3·00 cub. centims., *i.e.*, 6·00 per cent.
Organic solids .	·9555 grm., . . ,, 25·98 ,,	·1985 grm., . . ,, 5·39 ,,
Salts	·1945 ,, . . ,, 42·42 ,,	·0355 ,, . . ,, 7·74 ,, *

* Calculated on the serum salts. If added sodic fluoride is reckoned, absorption of ·0620 grm. salts, *i.e.*, 13·52 per cent.

HYDROSTATIC PRESSURES IN MILLIMETRES OF MERCURY.

Time.	Normal loop.	Fluoride loop.
11.50 start		
11.55	9	4
12.0	10	6
12.5	9–11	8
12.11	6	5
12.14	12	10
12.23	14	7
12.27	11	8
12.31	10	6·5
12.37	14	9·5
12.45	14	10
12.50 stop		

N.B.—There was no detachment of epithelium in this case.

I am, therefore, of opinion that the slight variations of hydrostatic pressure within the gut observed in the experiments are quite negligible as regards the main effect.

The effect of a drug on the absorption of serum is of course related to both the condition of the animal and the strength of the dose. Often a very weak dose will completely stop absorption if the animal is previously depressed by loss of blood, and this was the case in Experiment XIII., while on the other hand, in an animal in vigorous condition, the same dose may have little effect.

In the following experiment (XVI.) the treatment was the same as in Experiment XIII., but the dog was in splendid condition as regards circulation in the gut, and the effect, though evident, is slight.

EXPERIMENT XVI.—Dog, 20 kilos. Two 70 centims. Loops of Ileum. Duration of experiment, 40 minutes. One loop washed with ·8415 per cent. solution of sodic chloride, holding ·1 per cent. of sodic fluoride, the other with ·9804 per cent. solution of sodic chloride. Lowering of freezing point of each wash $= -·590°$ C.

	Organic solids.	Salts.
	grms.	grm.
Introduced into each loop 40 cub. centims. of own serum, holding . .	3·0000	·3680
Recovered: Normal loop, 10 cub. centims. serum, holding	1·3143	·0847
„ Fluoride washed loop, 15·5 cub. centims., holding . . .	1·1951	·1348

ABSORBED IN 40 MINUTES.

	Normal loop.	Fluoride washed loop.
Water . . .	30·00 cub. centims., *i.e.*, 75·00 per cent.	24·50 cub. centims., *i.e.*, 61·25 per cent.
Organic solids .	1·6857 grm., . . „ 56·19 „	1·8049 grm., . . „ 60·16 „
Salts	·2833 „ . . „ 76·98 „	·2332 „ . . „ 63·37 „

HYDROSTATIC PRESSURES.

Normal loop . . . . . 6·5 to 10 millims. of Hg.
Fluoride washed loop . . . . 7 to 10 „ „

LOWERINGS OF FREEZING POINT

Introduced serum.	Removed from fluoride loop.	Removed from normal loop.	Serum of dog at end of experiment.
– ·602° C.	– ·580° C.	– ·540° C.	– ·590° C.

As evident by the great absorption in 40 minutes this animal was in a very vigorous condition, and the effect of the fluoride wash is slight as compared with Experiment XIII.

(4) (a) *Weak Solution of Osmic Acid*, (b) *Atropine.*

Before terminating this part of the subject, instances of reductions of absorption of serum by other means may be noted.

In the following experiment (Experiment XVII.) a previous washing of the loop with very weak osmic acid (·0125 per cent.) solution in "normal saline" had a distinct effect upon absorption, while in the next experiment, XVIII., atropine sulphate added to ·18 per cent. to the serum evidently reduced the absorption.

EXPERIMENT XVII.—Dog, 24·5 kilos. Two 70 centims. Loops of Ileum. Duration of experiment, 1 hour. One loop washed with ·0125 per cent. solution of osmic acid in ·9804 per cent. solution of sodic chloride, the other with ·9804 per cent. solution of sodic chloride alone.

	Organic solids.	Salts.
	grms.	grm.
Introduced 50 cub. centims. of own serum, holding	3·7600	·4550
Recovered: Normal loop, 26·5 cub. centims. serum, holding	2·7110	·2199
„ Osmic washed loop, 33·0 cub. centims. serum, holding . .	2·8809	·2871

ABSORBED IN 1 HOUR.

	Normal loop.	Osmic washed loop.
Water . . .	23·50 cub. centims., *i.e.*, 47·00 per cent.	17·00 cub. centims., *i.e.*, 34·00 per cent.
Organic solids .	1·0490 grm., . . „ 27·63 „	·8791 grm., . . „ 23·38 „
Salts	·2351 „ . . „ 51·67 „	·1679 „ . . „ 36·90 „

HYDROSTATIC PRESSURES.

Normal loop . . . . . 6·5 to 9 millims. of Hg.
Osmic washed loop . . . . . 8 to 12 „ „

LOWERINGS OF FREEZING POINT.

Introduced serum.	Removed from osmic loop.	Removed from normal loop.	Serum of dog at end of experiment.
– ·590° C.	– ·560° C.	– ·530° C.	– ·620° C.

EXPERIMENT XVIII.—Dog, 15 kilos. Two 80 centims. Loops of Ileum. Duration of experiment, ½ hour. To the serum in the upper loop ·18 per cent. of sulphate of atropine was added. (·063 grm. atropine sulphate introduced.)

	Organic solids.	Salts.
	grms.	grm.
Introduced 35 cub. centims. serum, holding	2·3370 (2·4000 in atropine loop)	·3160
Recovered: Normal loop, 21·5 cub. centims. serum, holding	1·6630	·1881
„ Atropine loop, 25·0 cub. centims. serum, holding	1·9728	·2197

ABSORBED IN ½ HOUR.

	Normal loop.	Atropine loop.
Water . . .	13·50 cub. centims., *i.e.*, 38·57 per cent.	10·00 cub. centims., *i.e.*, 28·57 per cent.
Organic solids .	·6740 grm., . . „ 28·84 „	·4272 grm., . . „ 17·80 „
Salts	·1279 „ . . „ 40·47 „	·0936 „ . . „ 30·47 „

HYDROSTATIC PRESSURES.

Normal loop . . . . . 3 to 5 millims. of Hg.
Atropine loop . . . . . 4·5 to 5 „ „

LOWERINGS OF FREEZING POINT.

Introduced serum.	Removed from atropine loop.	Removed from normal loop.	Serum of dog at end of experiment.
– ·590° C.	– ·590° C.	– ·580° C.	– ·590° C.

DETAILS OF PROCESS OF ABSORPTION OF SERUM.

(1) *Absorption of Organic Solids.*

The general fact then having been, as I believe, established that the absorption of serum is due to the physiologically active mechanism of the cylinder cells of the gut, it is in the next instance necessary to study more closely the details of the process.

The first point worthy of notice in the process of absorption of serum in normal loops of gut is that the absorption of the organic constituents of the serum occurs more slowly than that of the salts and water, so that the concentration in organic solids of the serum removed from the experimental loop of gut is well in excess of that of the serum introduced. Some instances of the fact, which was noted also by HEIDENHAIN, are quoted in the first two columns of Table IV.

TABLE IV.—Absorption of Serum by Normal Loops of Gut. *Organic Solids are absorbed more slowly than Water. Salts are absorbed rather more quickly than Water.*

Per cent. of organic solids in serum.		Per cent. of salts in serum.		Lowering of freezing point.		Duration of experiment.
Introduced.	Removed.	Introduced.	Removed.	Introduced.	Removed.	
6·70	10·67	·90	·85	·590	·530	1 hour.
7·07	11·16	·91	·88	·590	·550	1 „
7·50	13·14	·92	·85	·600	·540	1 „
7·21	9·37	·91	·86	·600	·560	1 „
7·52	10·23	·91	·83	·590	·530	1 „
7·42	10·33	·93	·87	·590	·560	1 „
7·63	10·43	·92	·86	·600	·560	1 „
7·91	11·63	·92	·84	·595	·540	½ „
6·30	8·67	·97	·92	·620	·595	½ „
6·84	10·46	·98	·96	·600	·570	40 minutes.

The suggestion that this is solely the result of addition of organic solids to the serum in the gut from the *succus entericus* is, I think, negatived by comparing the result in a loop of gut poisoned with pilocarpine with that in one (in the same animal) poisoned with atropine.

If the rise in concentration of organic solids is due to an addition by secretion we should reckon a smaller absorption of organic solids in a pilocarpinised loop, than in one poisoned by atropine, for more organic solids of the *succus entericus* should enter the serum in the former than in the latter.

But as is evident in the following instance (Experiment XIX.) the absorption of organic solids in a pilocarpinised loop may considerably exceed that in an atropinised loop.

EXPERIMENT XIX.—Serum absorption. The slower absorption of organic solids in contrast to that of water is not merely *apparent* as a result of addition of proteids, &c., from *succus entericus*. If so, less absorption of organic solids should be reckoned in a pilocarpinised loop than in an atropinised loop in the same animal. Dog, 18 kilos. 80 centims. Loops of Gut. Duration of experiment, 30 minutes.

	Organic solids.	Salts.
	grms.	grm.
Introduced: Atropine loop, 50 cub. centims. serum, holding	3·5095	·4600
„ Pilocarpine loop, 50 cub. centims. serum, holding . . .	3·4855	·4600
Recovered: Atropine loop, 28·5 cub. centims., holding	2·5567	·2622
„ Pilocarpine loop, 21·5 cub. centims., holding	2·0403	·1935

ABSORBED IN 30 MINUTES.

	Atropine loop.	Pilocarpine loop.
Water. . .	21·5 cub. centims., *i.e.*, 43·00 per cent.	28·15 cub. centims., *i.e.*, 57·00 per cent.
Organic solids .	·9528 grm., . . „ 27·14 „	1·4452 grm., . . „ 41·46 „
Salts	·1978 „ *. . „ 43·00 „ *	·2665 „ . . „ 57·93 „

PRESSURES.

Atropine loop . . . . . 5 to 8 millims. of Hg.
Pilocarpine loop. . . . . 7 to 10 „ „

1 cub. centim. $\frac{3}{10}$ grm. mol. solution of pilocarp. nitrate and atrop. sulphate to 90 cub. centims. of serum, *i.e.*, ·129 per cent. atropine and ·081 per cent. pilocarpine.

Further, I have not been able in normal loops to detect any addition of mucus (acetic acid precipitate) to the serum, an observation which is, however, contrary to the experience of those who have worked with fistulous loops instead of those freshly prepared.

The suggestion that the phenomenon is due to filtration is, I believe, refuted by the experimental evidence against filtration already quoted, and I am bound in the

* Too low. Fusion of ash before carbon completely oxidised (*vide* Appendix, p. 291).

meantime to consider it as a specific part of the action of the gut cells, especially as the absorption of organic solids may be affected independently of that of water, as evident in the next experiment (Experiment XX.), where the use of skatol, a proteid decomposition product foreign to the small intestine, distinctly affects the absorption of organic solids of the serum while that of water remains the same as in the normal control loop.

EXPERIMENT XX.—Dog, 20 kilos. Two 80 centims. Loops of Ileum. Duration of experiment, $\frac{1}{2}$ hour. 6·5 milligrms. of skatol dissolved in serum introduced into the upper loop.

	Organic solids.	Salts.
	grms.	grm.
Introduced : Normal loop, 45 cub. centims. serum, holding	2·9205	·4275
„ Skatol loop, 45 cub. centims. serum, holding	2·9270	·4275
Recovered : Normal loop, 29 cub. centims. serum, holding	2·3113	·2610
„ Skatol loop, 29 cub. centims. serum, holding	2·5056	·2668

ABSORBED IN $\frac{1}{2}$ HOUR.

	Normal loop.	Skatol loop.
Water . . .	16·00 cub. centims., *i.e.*, 35·56 per cent.	16·00 cub. centims., *i.e.*, 35·56 per cent.
Organic solids .	·6092 grm., . . „ 20·86 „	·4214 grm., . . „ 14·39 „
Salts	·1665 „ . . „ 38·94 „	·1607 „ . . „ 37·58 „

HYDROSTATIC PRESSURES.

Normal loop	3 to 5 millims. Hg.
Skatol loop	6 to 8 „ „

Since the difference in the absorption of organic solids on the two sides amounts to ·1943 grm., and only ·0065 grm. of skatol was introduced, the effect is not due merely to the retention of the skatol.

(2) *Absorption of Salts.*

A second point brought out in the absorption of serum in normal loops of gut is that the salts of the serum are taken up a little faster than the water, and this is the more marked the more active the absorption.

HEIDENHAIN only quotes two experiments upon the absorption of serum in which he quantitatively estimated the salts, and came to the conclusion that salts and water are taken up at the same rate.

As a result of a large number of experiments, I am convinced that it is the rule for the salts to be taken up slightly faster than the water, so that the concentration in salts of the serum removed from the gut at the end of the experimental period is below that of the serum introduced.

This phenomenon is evident enough in the cases quoted in Table IV., p. 249.

That the conclusion is not merely due to errors in ash analysis is, I think, clear from the fact that the lowering of freezing point of the serum removed from the gut is not so great as that of the serum introduced, in spite of the higher concentration of organic solids in the former (*vide* TABLE IV.).

COMPARISON OF ABSORPTION WITH SECRETION.

When, therefore, an animal's own serum is placed in its gut, it is not simply taken up as such and passed on over into the blood, any more than the lymph taken up by a secretory cell is passed on as such into the gland lumen.

It is nearly eighty years now since TIEDEMANN and GMELIN compared the absorbing villus to an inverted secreting gland, but one cannot assess their comparison at a very high value, in spite of its possible truth, for FISCHER and DUTROCHET had not then published the first systematic experiments upon osmosis, and thirty years were to pass before LUDWIG'S demonstration of secretory pressure.

In attempting to obtain reliable data for such a comparison, our main difficulty, from the experimental point of view, is that our chemical facts must come from opposite sides of the active cells in the two cases. We study a secretion from the output side, an absorption from the intake, and though the matter of the output is in the end quantitatively that of the intake, the combinations (in secretion at any rate) are by no means the same, and it is therefore of little value in analysis to attempt to go beyond the gross quantities of water, organic solids, and salts.

Certain points of difference between a secretory act, as known in the salivary glands, and the absorption of serum may at once be alluded to.

(a) *Absence of Stimulant Action of Pilocarpine.*

Pilocarpine does not excite absorption as it does secretion, but depresses it like many other poisons. This conclusion is, moreover, not merely due to misinterpretation of results from an excess of secretion of *succus entericus* evoked by the pilocarpine, because, as seen in Experiment XVIII., p. 248, the absorption is greater in a lood poisoned with pilocarpine than in one poisoned with atropine, in which latter there is less tendency to secretion of *succus entericus*. An instance of reduction of absorption by pilocarpine is now cited in Experiment XXI.

EXPERIMENT XXI.—Dog, 27 kilos. Two 80 centims. Loops of Ileum. Duration of experiment, $\frac{1}{2}$ hour. The serum introduced into one loop held ·077 per cent. of pilocarpine nitrate (·0385 grm. of pilocarpine nitrate was introduced with the charge of serum).

	Organic solids.	Salts.
	grms.	grm.
Introduced 50 cub. centims. own serum, holding . . .	3·4800	·4650
	(3·5185 in pilocarpine loop)	·4650
Recovered: Normal loop, 32 cub. centims., holding . .	2·6528	·3040
,, Pilocarpine loop, 38 cub. centims., holding .	3·0552	·3496

ABSORBED IN ½ HOUR.

	Normal loop.	Pilocarpine loop.
Water. . . .	18·00 cub. centims., *i.e.*, 36·00 per cent.	12·00 cub. centims., *i.e.*, 24·00 per cent.
Organic solids .	·8272 grm., . . „ 23·77 „	·4633 grm., . . „ 13·16 „
Salts	·1610 „ *. . „ 34·62 „ *	·1154 „ . . „ 24·81 „

N.B.—Salivation came on 14 minutes after introduction of the pilocarpinised serum into the gut.

The smaller absorption of organic solids in proportion to water in the pilocarpine loop than in the normal loop, is not a secretion phenomenon, since the same relative reduction is seen in the atropine versus normal experiment (XVIII.) already quoted.

(b) *Absence of Evidence of Specific Nerve Fibres.*

Again I have not been able to find any evidence of fibres in the mesenteric nerves, excitation of which will produce an increase in the absorption of serum.

On the other hand, excitation of the mesenteric nerves during absorption, as a result of the concurrent anæmia from stimulation of vaso-constrictor fibres, always reduces the effect.

Two instances, Experiments XXII. and XXIII., of excitation of the mesenteric nerves during serum absorption are now quoted, the one in a normal dog, and the other in an animal atropinised to the extent of 5 milligrms. of atropine sulphate per kilo. of body weight, to exclude a secretion effect. It is evident that the result is practically the same in both cases.

EXPERIMENT XXII.—Dog, 20 kilos. Two 80 centims. Loops of Ileum. Duration of experiment, ½ hour. Mesenteric nerves of one loop excited by faradisation during the absorption period.

	Organic solids.	Salts.
	grms.	grm.
Introduced into each loop 50 cub. centims. of own serum, holding . .	4·0230	·4820
Recovered: Normal loop, 29 cub. centims. serum, holding	2·9023	·2703
„ Stimulated loop, 39 cub. centims. serum, holding . . .	3·4597	·3701

ABSORBED IN ½ HOUR.

	Normal loop.	Loop with nerves excited.
Water. . .	21·00 cub. centims., *i.e.*, 42·00 per cent.	11·00 cub. centims., *i.e.*, 22·00 per cent.
Organic solids .	1·1207 grm., . . „ 27·85 „	·5633 grm., . . „ 14·00 „
Salts	·2117 „ . . „ 43·92 „	·1119 „ . . „ 23·21 „

* Too low from fusion of ash before carbon completely oxidised.

HYDROSTATIC PRESSURES.

Normal loop	3 to 6 millims. of Hg.
Loop with nerves excited . . .	3 to 5 „ „

EXPERIMENT XXIII.—Dog, 20 kilos. Two 80 centims. Loops of Ileum. Duration of experiment, ½ hour. Animal atropinised to the extent of 5 milligrms. atropine sulphate per kilo. of body weight.

	Organic solids.	Salts.
	grms.	grm.
Introduced 40 cub. centims. of own serum, holding	2·7512	·3968
Recovered: Normal loop, 27·5 cub. centims. serum, holding	2·3175	·2510
„ Stimulated loop, 30·5 cub. centims. serum, holding . . .	2·3866	·2882

ABSORBED IN ½ HOUR.

	Normal loop.	Loop with nerves excited.
Water. . . .	12·50 cub. centims., *i.e.*, 31·25 per cent.	9·50 cub. centims., *i.e.*, 23·75 per cent.
Organic solids .	·4337 grm., . . „ 15·76 „	·3646 grm., . . „ 13·25 „
Salts	·1458 „ . . „ 36·74 „	·1076 „ . . „ 27·11 „

HYDROSTATIC PRESSURES.

Normal loop	5 to 7 millims. of Hg.
Loop with nerves excited . . .	5 to 7 „ „

So far, then, as can be seen at present, the activity of the epithelial cells is, in the main, a function of blood supply, and the effect of reduction in absorption of serum obtained by excitation of the mesenteric nerves is the result of lowering of nutrition of the cells by the vaso-constrictive anæmia produced.

In previously published experiments upon the absorption of peptone, I found that if the mesenteric nerves are excited during a temporary anæmia produced by clamping the mesenteric arteries, the absorption of peptone is the same as in a control loop simply made anæmic, but with either intact or cut nerves.

(c) *Failure to Demonstrate* "HEIDENHAIN'S *Law.*"

The differences just alluded to in the physiological mechanism of serum absorption from that obtaining in secretion in the salivary glands will not make us hopeful of finding similarity of action between intestinal and salivary cells *in detail*, though the functioning of the two sorts of cells may lead to the same end result in each instance.

It at one time appeared hopeful to study the concentrations in organic solids and salts of the *uptake* by the cells of the gut wall, and to compare them with the concentrations in these constituents of the *output* of the salivary glands at different rates of absorption and secretion respectively, but the experimental methods of varying the rate of absorption are at present so limited in contrast to the methods open to the student of salivary secretion that I cannot say that I have yet gathered fruit from this tree.

It will be remembered that HEIDENHAIN, WERTHER, and LANGLEY and FLETCHER found that when salivary secretion is excited by chorda stimulation or by pilocarpine, the concentration in salts of the saliva is a function of the rapidity of secretion, while with the concentration in organic solids no definite rule appears to hold.

With slowing of secretion of saliva, then, the concentration in salts of the fluid secreted falls.

Anæmia of the gland, however, was found to raise the concentration both of organic solids and salts in the secreted saliva, though it naturally slowed the rate of secretion, with a given stimulus, by diminishing the irritability of the gland cells.

It followed that with excitation of the sympathetic supply to the gland, when anæmia is concomitant with secretion, the rule should not apply, and it was found experimentally that the flow of saliva could be cut down from a chorda or pilocarpine level, without any drop in the concentration of salts in the saliva, while at the same time the concentration in organic solids rose.

The presence of anæmia then upsets the so-called "HEIDENHAIN'S law" in reference to the relation of concentration in salts to rate of secretion, and unfortunately, so far, I have devised no other method of reducing the rate of absorption of serum, than by anæmia, if we exclude drugs, make it a *sine qua non* that the epithelium be kept *in situ*, and restrict ourselves to comparisons of the results in two loops of gut in one and the same animal.

In the following Table (V.) it is evident that though the rate of absorption is considerably reduced, there is no cutting down in the concentration in salts of the solution taken up from the serum by the gut wall, nor is there any marked change in the concentration in organic solids of the solution taken up in the two loops respectively. In fact, the absorption of all the constituents of the serum is reduced in equal degree by anæmic reduction, provided the epithelium is uninjured.

TABLE V.—Serum Absorption. Simple Anæmic Reduction without Injury to Epithelium.

Nature of experiment.	Rate of absorption in cub. centims. per minute.		*Concentration of solution taken up by gut wall from introduced serum.*			
			Organic solids, per cent.		Salts, per cent.	
	Normal.	Anæmic.	Normal.	Anæmic.	Normal.	Anæmic.
Previous anæmia by clamping vessels. (No loss of epithelium)	·55	·37	3·27	3·28	1·08	1·04
Stimulation of mesenteric nerves. . .	·62	·37	3·21	2·92	·99	1·06
„ „ „ . . .	·63	·40	3·78	3·38	1·00	·99
„ „ „ . . .	·70	·37	5·33	5·12	1·00	1·01
„ in atropinised animal . .	·41	·31	3·46	3·83	1·16	1·13

Reduction in rate of absorption without marked change in concentration of the solution taken up by the gut wall.

It has already been pointed out that in normal loops the concentration in salts of the solution taken up from the serum exceeds that in the original serum placed in the loop (*i.e.*, salt is absorbed rather faster than water from serum).

This is not an unknown phenomenon in secretion, for in one instance WERTHER found a percentage concentration of salts in the sub-lingual saliva of 1·34, which is considerably in excess of the blood concentration.

The attachment of the intestinal epithelium to the basement membrane is so slight, and so easily affected, that it is difficult to keep an anæmic period short enough to prevent any loss of epithelium, and yet long enough to depress its activity so much that during the absorption period, when the blood is again allowed to circulate, and the loop naturally becomes hyperæmic, a distinct reduction of activity shall be evident.

Directly partial detachment of epithelium is produced, whether by drugs or anæmia, a new phenomenon makes its appearance.

While the concentration in salts of the solution taken up by the gut wall remains practically the same in the injured and normal loops, the concentration in organic solids, on the other hand, of the solution passing into the gut wall is invariably higher on the injured than on the normal side, in spite of the favourable conditions for transudation into the gut from the blood induced by detachment of epithelium. (An albuminous transudate would lead to a reckoning of diminution in concentration of organic solids in the fluid absorbed, the reverse of what experiment shows to be the case.)

Some instances of this are presented in the next Table (VI.).

TABLE VI.—Serum Absorption. Reduction with Injury to Epithelium.

Nature of experiment.	Rate of absorption in cub. centims. per minute.		*Concentration of solution taken up by gut wall.*			
			Organic solids, per cent.		Salts, per cent.	
	Normal.	Injured.	Normal.	Injured.	Normal.	Injured.
I. Treatment with sodium fluoride. .	·34	·16	3·74	7·99	1·08	·99
II. ,, ,, ,, . .	·45	·13	4·94	7·52	·98	1·03
III. ,, ,, ,, . .	·34	·05	4·77	6·61	·97	1·18
IV. Previous anæmia. Very marked loss of epithelium	·50	·07	5·08	14·46	1·03	1·14
V. Osmic wash, ·0125 per cent. . . .	·39	·28	4·47	5·17	1·00	·98

Concentration in organic solids of solution taken up from serum by gut wall is considerably greater in the injured loop than in the normal loop.

This effect is the more marked the greater the removal of the epithelium (see Experiment IV., in Table VI., especially), and at present I consider it simply a physical result directly connected with the removal of epithelium.

If the juice of the villus parenchyma is a filtration lymph its salt concentration is probably that of the plasma, while its concentration in organic solids (proteids especially) is below that of the plasma. Since we place the animal's own serum into its intestine, the partial osmotic pressure of the salts in the solution in the gut will be that of the villus juice, while that of the organic solids will be above the partial osmotic pressure in the villus juice, so that conditions for diffusion exist in the latter case and not in the former. In addition it is of course possible that the conditions for *adsorption* of organic solids is altered by the treatment bestowed upon the epithelium.

Occasionally the phenomenon is so marked that in spite of the great reduction in absorption of water and salt from the serum induced by the treatment of the epithelium the absolute absorption of organic solids may be reckoned the same, or even a little greater, on the injured side than on the normal.

Such an instance is quoted in Experiment XXIV.

EXPERIMENT XXIV.—Dog, 23·5 kilos. Two 80 centims. Loops of Ileum. Duration of experiment, 1 hour. One loop washed ·1 per cent. sodic fluoride in ·8415 per cent. sodic chloride solution, the other with ·9804 per cent. solution of sodic chloride. (Lowering of freezing point of wash in each case —·590° C.) The serum introduced into the fluoride washed loop had had sodic fluoride to ·043 per cent. added to it.

	Organic solids.	Salts.
	grms.	grm.
Introduced: Normal loop, 50 cub. centims. own serum, holding . .	3·4750	·4750
Fluoride loop, 50 cub. centims. fluoride serum, holding .	3·4750	·4965
Recovered: Normal loop, 30 cub. centims. serum, holding	2·7270	·2580
Fluoride loop, 40 cub. centims. serum, holding	2·6760	·3760

ABSORBED IN 1 HOUR.

	Normal loop.	Fluoride loop.
Water . . .	20·00 cub. centims., *i.e.*, 40·00 per cent.	10·00 cub. centims., *i.e.*, 20·00 per cent.
Organic solids .	·**7480** grm., . . „ **21·52** „	·**7990** grm., . . „ **22·99** „
Salts	·2170 „ . . „ 45·68 „	·1205 „ . . „ 24·27 „
		(·0990 „ . . „ 20·84 „ if added fluoride is not reckoned)

LOWERINGS OF FREEZING POINT.

Introduced normal serum.	Introduced fluoride serum.	Recovered normal serum.	Recovered fluoride serum.	Serum of dog at end of experiment.
– ·610° C.	– ·630° C.	– ·560° C.	– ·622° C.	– ·610° C.

HYDROSTATIC PRESSURES.

Normal loop . . . . . 4·5 to 8 millims. of Hg.
Fluoride loop . . . . . 4·5 to 12 „ „

ABSENCE OF EFFECT OF BILE ON ABSORPTION OF SERUM.

Since it was sometimes noted that one of the loops of gut, in spite of the previous washing with normal salt solution, was more bile-stained than the other, a series of experiments was conducted to determine whether bile or taurocholate of soda affects the absorption of serum.

Dried (over sulphuric acid *in vacuo*) dog's bile or taurocholate of soda, prepared from ox bile, was added to the animal's own serum before introduction into one loop of gut, a normal control loop filled with normal serum being used at the same time.

In one instance the taurocholate, at a concentration in the serum of ·625 per cent. in the upper loop, appeared to have a quickening effect upon absorption, but the remaining experiments, collected in Table VII., gave a negative result, and I conclude that bile or taurocholate of soda have no stimulating effect upon the absorption of serum.

TABLE VII.—Absence of Effect of Bile and Taurocholate of Soda upon Absorption of Serum.

Number of experiment.	Weight of dog in kilogrammes.	Duration of experiment in minutes.	Length of loops of gut in centims.	Distance of lower loop from ileo-cæcal valve in centims.	Volume of own serum introduced into each loop in cub. centims.	Absorptions.					
						Normal loop.			Bile or taurocholate loop.		
						Water.	Organic solids.	Salts.	Water.	Organic solids.	Salts.
I.	37	30	80	100	50	25 cub. centims. = 50·00 per cent.	1·0487 grm. = 26·49 per cent.	·2513 grm. = 54·33 per cent.	26 cub. centims. = 52·00 per cent.	1·1264 grm. = 26·14 per cent.	·2754 grm. = 55·53 per cent.
II.	17·5	30	80	75	50	22 cub. centims. = 44·00 per cent.	·7951 grm. = 27·12 per cent.	·2153 grm. = 44·99 per cent.	22 cub. centims. = 44·00 per cent.	·7605 grm. = 21·13 per cent.	·2505 grm. = 46·65 per cent.
III.	22	30	80	100	50	25 cub. centims. = 50·00 per cent.	1·1375 grm. = 33·75 per cent.	·2350 grm. = 51·08 per cent.	20 cub. centims. = 40·00 per cent.	1·0344 grm. = 28·17 per cent.	·2096 grm. = 42·89 per cent.
IV.	21	20	80	75	30	19 cub. centims. = 63·34 per cent.	1·0589 grm. = 51·59 per cent.	·1865 grm. = 64·09 per cent.	19 cub. centims. = 63·34 per cent.	1·2430 grm. = 53·96 per cent.	·2383 grm. = 67·77 per cent.
V.	28	30	80	100	50	22 cub. centims. = 44·00 per cent.	·7222 grm. = 22·95 per cent.	·2248 grm. = 46·44 per cent.	21 cub. centims. = 42·00 per cent.	·7013 grm. = 20·92 per cent.	·2489 grm. = 46·74 per cent.

Experiments I., II., and III. are with dried (*in vacuo* over H_2SO_4) dog's bile added to the serum.

Experiments IV. and V. with taurocholate of soda prepared from ox bile.

In Experiments I. and III. the ash of the dried bile was 8·69 per cent., in Experiment II. it was 8·06 per cent.

The taurocholate of soda used in Experiments IV. and V. had an ash of 19·43 per cent. estimated as sulphates.

In all cases the organic and inorganic solids of the bile or taurocholate added to the serum are reckoned in the calculations.

Except in the case of Experiment III. the animals used were fasting. The dog in Experiment III. was in full digestion with white lacteals.

In Experiments II., III., and IV. the normal loop was the upper of the two, in Experiments I. and V. the normal loop was the nearer to the ileo-cæcal valve.

The concentration of the dried bile or taurocholate in the serum was as follows :—

Experiment I.	·77 per cent.	Bile (dry).
,, II.	1·45 ,,	Bile (dry).
,, III.	·66 ,,	Bile (dry).
,, IV.	1·04 ,,	Sodium taurocholate.
,, V.	·5 ,,	Sodium taurocholate.

The hydrostatic pressures in millims. of Hg. in the loops during the experiments were as follows :—

	Normal.	Bile or taurocholate.
Experiment I.	5 to 13	6 to 13
,, II.	5 to 7	4 to 6
,, III.	9 to 10	7·5 to 10
,, IV.	4 to 7	4 to 7
,, V.	3·5 to 7·5	3·5 to 7·5

Lowerings of Freezing Point

Experiment.	Introduced normal serum.	Introduced bile or taurocholate serum.	Removed normal serum.	Removed bile or taurocholate serum.	Serum of dog at end of experiment.
	°C.	°C.	°C.	°C.	°C.
I.	– ·595	– ·610	– ·540	– ·570	– ·598
II.	– ·580	– ·615	– ·545	– ·575	– ·590
III.	– ·590	– ·620	– ·590	– ·600	– ·610
IV.	– ·590	– ·688	– ·600	– ·600	– ·610
V.	– ·620	– ·670	– ·595	– ·615	– ·630

Stimulation of Absorption.

It has been seen that the rapidity of absorption of serum is dependent upon blood supply to normal epithelium, and that, as by the use of atropine, the absorption can be reduced though the blood supply is, if anything, better in the atropinised loop than in the normal.

It is hence of importance to determine whether absorption can be increased without increase of blood supply, by some stimulant substance.

The experiments of Farnsteiner and v. Scanzoni, pupils of Tappeiner, on the absorption of glucose and peptone in dogs with a Vella fistula, indicate that certain stimulant substances, added to the solutions placed in the gut, increase the rate of absorption. They found oil of mustard (1 in 1000), oil of cinnamon (1 in 100), oil of peppermint (1 in 250), orexin, and ethyl alcohol (5 per cent.) increased the amount

of glucose or peptone absorbed, while stronger solutions injured the gut wall and reduced absorption, though probably the blood supply was better with the stronger than with the weaker solutions. Ethyl alcohol was found to be the most effective stimulant. Bitters (quassia and cetraria) are, according to FARNSTEINER, without effect.

HOPPE-SEYLER, VOIT and BAUER, and v. REGÉCZY have found that sodium chloride added to proteid solutions aids their diffusion, an observation which is difficult to understand in the light of the work of GÜRBER, who shows that there is no combination of sodium chloride with proteids; and, according to VOIT and BAUER, it matters not whether the sodium chloride is added to the proteid solution or to the water into which it is set to diffuse.

VOIT and BAUER found it necessary to add NaCl to the extent of 2·5 per cent. to egg albumin solutions introduced into the rectum in order to get any absorption, but in the small gut (comparing results in different animals) sodium chloride, added to 4·8 per cent. to solutions of egg albumin, does not affect the rapidity of absorption of the albumen, according to their experiments.

Finally, FARNSTEINER increased the absorption of peptone in the small gut by adding sodium chloride to ·5 per cent. of the solution.

I have tested the effect of ethyl alcohol upon the absorption of serum, and find that, provided the epithelium is uninjured, it does have the effect of increasing the absorption, especially of the organic solids. One can add alcohol to serum up to 5 per cent. (drop by drop with rapid stirring) without any immediate precipitation. The natural tendency to proteid precipitation by alcohol should, by taking the proteids out of solution, tend to diminish absorption thereof, but experiment indicates that the absorption of organic solids is increased. With such a strength of alcohol there is no evidence of any hyperæmia of the gut wall whatever, and I am therefore inclined to believe that the result is due to stimulation of cells rather than to improvement in nutrition of cells as a result of increased blood supply.

The two following experiments, Experiments XXV. and XXVI., are cases of success in the one instance with uninjured epithelium, and failure in the other with injured epithelium, in increasing serum absorption by means of weak alcohol.

EXPERIMENT XXV.—Absorption of alcoholic serum (5 per cent. by volume), in *uninjured* loop. Dog, 14 kilos. Two 60 centims. Loops of Ileum. Duration of experiment, ½ hour.

	Organic solids.	Salts.
	grms.	grm.
Introduced into each loop 40 cub. centims. own serum, holding . . .	2·8232	·3808
Recovered : Normal loop, 24 cub. centims., holding	2·4514	·2220
,, Alcoholic loop, 20 cub. centims., holding	1·9630	·1770

ABSORBED IN ½ HOUR.

	Normal loop.	Alcoholic loop.
Water . . .	16·00 cub. centims., *i.e.*, 40·00 per cent.	20·00 cub. centims., *i.e.*, 50·00 per cent.
Organic solids .	·3718 grm., . . „ 13·17 „	·8602 grm., . . „ 30·47 „
Salts	·1588 „ . . „ 41·70 „	·2038 „ . . „ 53·52 „

NOTE.—No visible excess of vascularity in mucosa of alcoholic loop. No ecchymoses.

EXPERIMENT XXVI.—Absorption of alcoholic serum (3·3 per cent. by volume), with *loss of epithelium.* Dog, 18·5 kilos. Two 60 centims. Loops of Ileum. Duration of experiment, ½ hour.

	Organic solids.	Salts.
	grms.	grm.
Introduced into each loop 40 cub. centims. serum, holding.	2·7348	·3852
Recovered: Normal loop, 24·5 cub. centims., holding	2·0105	·2239
„ Alcoholic loop (epithelium detached), 24·5 cub. centims., holding.	2·1317	·2276

ABSORBED IN ½ HOUR.

	Normal loop.	Alcoholic loop *with injured epithelium.*
Water . .	15·50 cub. centims., *i.e.*, 38·75 per cent.	15·50 cub. centims., *i.e.*, 38·75 per cent.
Organic solids .	·7243 grm., . . „ 26·48 „	·6031 grm., . . „ 20·05 „
Salts	·1613 „ . . „ 41·87 „	·1576 „ . . „ 40·91 „

HYDROSTATIC PRESSURES.

Normal loop . . . . . 6 to 8 millims. of Hg.
Alcoholic loop . . . . . 8 to 11 „ „

THE ABSORPTION OF SERUM IN DIFFERENT REGIONS OF THE INTESTINE.

(1) UPPER AND LOWER REGIONS OF ILEUM.

Since I have been unable to find any experiments upon this subject, the following may be of interest as indicating that there are differences of action of the intestinal wall upon the serum placed in contact therewith, in different regions of the intestinal tract.

In comparisons of the absorption in the upper ileum, with the tract in immediate continuity with the cæcum, two points must be at once noted. In the first place the greatest care is necessary in handling the upper ileum if one is to avoid loss of epithelium, especially in the case of a previously bled dog, and many results have had

to be discarded, since on removing the serum from the upper loop at the end of the experiment, it was found that some epithelium had been detached, and that the result was therefore of no value.

In the second place, the anatomical fact that the villi of the lowest region of the ileum are richer in goblet cells than those of the upper reaches, is noted, because the absorption of the organic solids of the serum is found experimentally to be both absolutely, and in proportion to water, greater in the lower than in the upper regions, which, further, does away with the suggestion that the ordinary deficiency of absorption of organic solids, noted in an earlier part of the paper (pp. 249–250), as a characteristic of normal serum absorptions, is simply due to the addition of the secretion of goblet cells.

These very simple experiments with normal loops serve further to impress the point that the absorption of the organic solids of the serum is largely independent of the absorption of water, and, as seen in Experiment III. in Table VIII. p. 264, the absorption of organic solids in the lower ileum may exceed that in the upper at a time when the absorption of water is only half that in the upper loop.

This fact is not likely to be associated with any ferment action producing peptone from the serum, for not only would such ferment action be more likely to make itself felt in the upper than in the lower ileum, but, as seen in Table XIX., p. 286, the actual absorption of peptone is less in the lower than in the upper regions.

Experiments upon the absorption of serum in upper and lower regions of the ileum are now quoted in Table VIII., p. 264.

The following points will be evident from a perusal of the figures in this table :—

1. The absolute absorption of the organic solids of serum is greater in the lowest part of the ileum than in the region about two metres above the cæcum in large dogs.
2. In proportion to water there is greater absorption of organic solids in the lower region than in the upper.
3. The absorption of salts from the serum varies roughly with that of the water, but in proportion to the water absorption it is greater in the lower than in the upper regions.

(2) Ileum and Colon.

Turning to a comparison of the absorption of serum in the colon with that in the middle region of the ileum, we find the reverse to obtain to that found in a comparison of the upper and lower regions of the ileum itself so far as regards the absorption of organic solids. The absorption of organic solids is not only much less in the colon than in the ileum but less in proportion to water.

A marked feature of absorption of serum in the colon appears to be an exaggeration of the absorption of salt in proportion to water. Slight excess of salt absorption over that of water has already been noted as a constant feature throughout the small gut, and, as seen in Table VIII., it is a more marked feature in the lower than in the

TABLE VIII.—Comparisons of Absorptions of Dog's Own Serum in Upper and Lower Regions of Ileum. In all cases the Lower Loop commences at the Ileo-cæcal Valve.

Number of experiment.	Duration of experiment in minutes.	Length of loops in centims.	Distance of upper loop from ileo-cæcal valve in centims.	Volume of own serum introduced into each loop in cub. centims.	Weight of dog in kilo-grammes.	Absorptions					
						Upper loop.			Lower loop.		
						Water.	Organic solids.	Salts.	Water.	Organic solids.	Salts.
I.	30	80	230	40	22	15·50 cub. centims. = 38·75 per cent.	·3388 grm. = 12·17 per cent.	·1436 grm. = 39·36 per cent.	14·50 cub. centims. = 36·25 per cent.	·5759 grm. = 20·69 per cent.	·1420 grm. = 38·92 per cent.
II.	30	80	200	50	18	11·00 cub. centims. = 22·00 per cent.	·1914 grm. = 5·05 per cent.	·1090 grm. = 23·26 per cent.	13·00 cub. centims. = 26·00 per cent.	·3910 grm. = 10·32 per cent.	·1492 grm. = 31·84 per cent.
III.	30	Lower 55 Upper 50	205	30	24	15·00 cub. centims. = 50·00 per cent.	·3102 grm. = 14·45 per cent.	·1413 grm. = 49·68 per cent.	7·50 cub. centims. = 25·00 per cent.	·3564 grm. = 16·61 per cent.	·0852 grm. = 29·95 per cent.

In Experiment III. the gut surfaces as measured by a gelatine cast were, in *upper* loop 290 sq. centims., in *lower* loop 302 sq. centims.

Experiment.	$\frac{\text{Per cent. water absorbed}}{\text{Per cent. organic solids absorbed}}$		$\frac{\text{Per cent. water absorbed}}{\text{Per cent. salts absorbed}}$	
	Upper.	Lower.	Upper.	Lower.
I.	3·18	1·75	·98	·93
II.	4·35	2·52	·94	·81
III.	3·46	1·50	1·00	·71

TABLE IX.—Comparisons of Absorptions of Dog's Own Serum in Colon and Middle of Ileum. In all cases the Loop of Colon was measured off from the Cæcum towards the Rectum.

Number of experiment.	Duration of experiment in minutes.	Lengths of loops in centims.	Surface of loops in sq. centims.	Distance of loop of ileum from ileo-cæcal valve in centims.	Volume of dog's own serum introduced in cub. centims.	Weight of dog in kilogrammes.	Absorptions.					
							Ileum.			Colon.		
							Water.	Organic solids.	Salts.	Water.	Organic solids.	Salts.
I.	30	Ileum 40 Colon 24	232 216	75	40	22	12·50 cub. centims. = 31·25 per cent.	·5187 grm. = 19·76 per cent.	·1233 grm. = 33·25 per cent.	3·50 cub. centims. = 8·75 per cent.	·0280 grm. = 1·06 per cent. Added	·0420 grm. = 11·32 per cent.
II.	30	Ileum 45 Colon 26·5	261 252	100	35	30	8·00 cub. centims. = 22·85 per cent.	·3679 grm. = 16·08 per cent.	·0758 grm. = 23·18 per cent.	8·00 cub. centims. = 22·85 per cent.	·2826 grm. = 12·35 per cent.	·0855 grm. = 26·15 per cent.
III.	30	Ileum 46 Colon 27·5	239 275	100	35	17	10·50 cub. centims. = 30·00 per cent.	·3875 grm. = 17·41 per cent.	·0878 grm. = 27·21 per cent.*	6·00 cub. centims. = 17·14 per cent.	·1509 grm. = 6·78 per cent.	·0597 grm. = 18·50 per cent.
IV.	30	Ileum 37·5 Colon 22·5	236 232	100	35	19	6·00 cub. centims. = 17·14 per cent.	·2700 grm. = 10·03 per cent.	·0576 grm. = 17·14 per cent.	1·50 cub. centims. = 4·28 per cent.	·0068 grm. = ·25 per cent.	·0292 grm. = 8·69 per cent.

Experiment.	$\frac{\text{Per cent. water absorbed}}{\text{Per cent. organic solids absorbed}}$		$\frac{\text{Per cent. water absorbed}}{\text{Per cent. salts absorbed}}$	
	Ileum.	Colon.	Ileum.	Colon.
I.	1·58	∞	94	·77
II.	1·42	1·85	·98	·88
III.	1·72	2·53	1·10	·92
IV.	1·72	17·12	1·00	·49

* Too low from fusion of ash.

upper ileum, but it reaches its highest development in the colon. It might be thought that the salt absorption is more masked by secretion in the ileum than in the colon, but the results with water, placed in Table XXI., p. 288, do not show, from the lowerings of freezing point, any greater addition of salts to the fluid in the gut in the ileum than in the colon.

No ferments are, according to KLUG and KORECK, secreted by the glands of the colon, which apparently only secrete a slime for lubrication, and I have noted no difference in results whether the fæces removed from the colon were dry or moist.

The results of the experiments with absorptions of serum in ileum and colon are included in Table IX., p. 265.

The following conclusions are arrived at from a perusal of the figures in Table IX. :—

1. The absolute absorptions of the organic solids of serum are much less in the colon than in the ileum, and less in proportion to the surface as measured by a gelatine cast.
2. In proportion to water the absorption of organic solids is less in the colon than in the ileum.
3. The absorption of salt from the serum varies in the rough with that of the water in the two sections of gut, but in proportion to the water absorption the salt absorption is greater in the colon than in the ileum, and this phenomenon is more marked than in a comparison of the lower with the upper regions of the ileum.

If, however, a comparison is made between absorptions of serum in normal colon, with ileum, the epithelium of which has been damaged, it is seen that the colon absorbs the more (absolutely) of all constituents in proportion to the surface as measured by a gelatine cast, and the differences in the ratios of absorption of organic solids and salts to water, visible in the normal, no longer obtain.

An instance of such an experiment is quoted in Experiment XXVII.

EXPERIMENT XXVII.—Dog, 22 kilos. Loops of Colon and Ileum (100 centims. above ileo-cæcal valve). Duration of experiment, $\frac{1}{2}$ hour.

AREA OF INNER SURFACES BY GELATINE CASTS.

Ileum	253 sq. centims.
Colon	257 „

Great loss of epithelium from ileum—none from colon.

	Organic solids.	Salts.
	grms.	grm.
Introduced into each 40 cub. centims. of own serum, holding	2·6996	·3804
Recovered : Ileum, 34 cub. centims., holding	2·5079	·3243
„ Colon, 30 cub. centims., holding	2·3445	·2775

ABSORBED IN ½ HOUR.

	Ileum.	Colon.
Water. . . .	6·00 cub. centims., *i.e.*, 15·00 per cent.	10·00 cub. centims., *i.e.*, 25·00 per cent.
Organic solids .	·1917 grm., . . „ 7·10 „	·3551 grm., . . „ 13·15 „
Salts	·0561 „ . . „ 14·75 „	·1029 „ . . „ 27·05 „

RATIOS.

ILEUM.		COLON.	
Per cent. water absorbed. / Per cent. organic solids absorbed.	Per cent. water absorbed. / Per cent. salts absorbed.	Per cent. water absorbed. / Per cent. organic solids absorbed.	Per cent. water absorbed. / Per cent. salts absorbed.
2·11	1·01	1·90	·92

LOWERINGS OF FREEZING POINT.

Introduced serum.	Removed from ileum.	Removed from colon.
– ·600° C.	– ·600° C.	– ·580° C.

THE ABSORPTION OF WATER AND SOLUTIONS (OF GLUCOSE AND PEPTONE).

THE RELATION OF WATER ABSORPTION TO THE PHYSIOLOGICAL CONDITION OF THE GUT WALL.

If, as a result of consideration of the foregoing experiments with serum it is admitted that the absorption of serum is inexplicable upon the basis of osmosis and filtration, and at present demands the assumption of cell activity, seeing that, by the nature of the case, osmosis, filtration, and *adsorption* can be excluded, we naturally ask what evidence there is for or against any participation of the cells in the absorption of water and solutions, in which cases osmotic and *adsorptive* factors indubitably play a part?

Is there any clear evidence that intestinal absorption of solutions can proceed by simple physical processes, independent of any participation whatever of the epithelial cells?

HÖBER has quite recently maintained that this question can be answered in the affirmative in the case of solutions of salts, selecting these bodies on the hypothesis that they enter the arena of the cell metabolism to a far less extent than ordinary nutritive substances, and so escape the action of the cells lining the gut.

His thesis is that the rapidity of the intestinal absorption of salts varies as the rapidity of diffusion of the salts, and that the absorption of salt solutions is practically confined to the intercellular cement channel.

Several objections may be raised to the general application of this statement.

Though the action of the cells on the salts may possibly be ignored, one cannot, as does HÖBER, disregard the action of the salts on the cells, and conclude that because the absorption of solutions of different salts quite foreign to the gut membrane, in many cases varies as the rapidity of diffusion, that therefore the same law holds in the absorption of the normal salts of the aliment. Since he states, on p. 268 of his paper, that he found ·24 to ·40 per cent. of sodic chloride in the fluid in the gut at the end of an experiment (after thirteen consecutive absorptions in one loop of gut of various salt solutions), it is evident considerable epithelial injury took place.

The absorptions of the salts are, moreover, deduced from the absorptions of the water in which they were dissolved, which is not permissible if the salts act on the cells and thereby affect their orienting power for the blood salts, and so indirectly the osmotic pressure of the solution in the gut. The rapidity of absorption of a salt solution from the intestine is not merely a function of its original osmotic pressure in relation to that of the plasma and the rapidity with which this is affected by the diffusion of the salt into the blood, but also of the extent to which blood salts can enter it, and this, as COHNHEIM'S and my own experiments, to be quoted immediately, show, depends upon the condition of the epithelium, which may be affected by the substance used in the experiment.

One of the most notable exceptions to HÖBER'S rule, and one to which he himself draws attention, is that of the series sodic chloride, bromide, and iodide, in which case, though the diffusion rapidities are practically the same, the rates of absorption, calculated by his method, are utterly different, and he has to resort to an assumption of imbibition and swelling of the cement between the cells to explain the slow absorption of the iodide.

It must be noted also that the diffusion rapidities used as the physical basis of the argument are those in water, and not in the complex of electrolytes in solution in blood plasma.

The slow absorption, deduced by his method, of fluorides and oxalates in relation to their rapidities of diffusion is accredited on p. 263 to "interepithelische Anomalien."

Finally, even HÖBER is reduced to a "mechanism" to explain the orientation of the blood salts, but places it in the interepithelial cement instead of in the protoplasm of the cells.

(1.) *The Conditions for Entrance of Blood Salts into the Gut Lumen.*

It is obviously of paramount importance, in questions of absorption of solutions (directly as concerns the water absorption, and indirectly as this latter affects the concentration of the substance in solution in the gut from time to time), to know the condition of the gut wall and especially the epithelium, since the relation of the osmotic pressures on the two sides of the membrane is largely dependent, as O. COHNHEIM was the first to show, upon its power of holding back the blood salts.

The results of LEUBUSCHER, GUMILEWSKI, HEIDENHAIN, and BALDI indicating that the water of weak solutions of sodic chloride is more rapidly absorbed than distilled water, are in part undoubtedly due to the fact that distilled water by injury to the epithelium allows the blood salts to enter the gut easily, so that a difference of osmotic pressure on the two sides of the membrane cannot be kept up to the degree which is the case when, with weak salt solution and normal epithelium, substances in solution in the blood can exert their osmotic pressure almost to the full on the water in the gut.

The effect of the nature of the introduced solution upon the epithelium and so indirectly upon the entrance of the sodic chloride of the blood is clear in the next quoted experiment, XXVIII., where the quantity of sodic chloride entering the gut from the blood is estimated in a loop filled with distilled water as against a similar loop filled with a 5·74 per cent. solution of glucose ($\Delta = -\cdot590$).

EXPERIMENT XXVIII.—Dog, 18 kilos. Two 41 centims. Loops of Ileum in continuity. Duration of experiment, 15 minutes.

	Upper loop.	Lower loop.
Introduced . .	30 cub. centims. of 5·74 per cent. solution of glucose	30 cub. centims of distilled water.

WATER.

	Recovered.	Absorbed.	Absorbed in per cent. of introduced.
	cub. centims.	cub. centims.	per cent.
Glucose loop	28	2	6·67
Water loop	18	12	40·00

SODIC CHLORIDE ADDED FROM BLOOD.

Glucose loop . . . ·016 grm., *i.e.*, ·057 per cent. in fluid in gut at end of experiment.
Water loop . . . . ·058 „ „ ·322 „ „ „ „
Glucose absorbed . . ·420 „ „ 24·4 „

Hence more than three times as much sodic chloride entered the water than the glucose solution from the blood.

The presence of glucose in solution will physically slightly hinder the diffusion in of *sodic chloride*, but not to the extent in this experiment.

In an experiment with diffusion of ·92 per cent. sodic chloride solution through parchment paper into, respectively, 6 per cent. and 2·3 per cent. solutions of glucose, O. COHNHEIM (p. 146) found, in five hours, diffusion into 6 per cent. glucose solution gave a concentration of ·7 per cent. of sodic chloride, while diffusion into 2·3 per cent. glucose solution gave an end concentration of ·73 per cent. of sodic chloride.

Over three and a-half times as much sodic chloride entered the water as the

glucose solution, which is far more than can be accounted for by the presence of the glucose physically retarding the diffusion of salt.

If the gut epithelium is removed by anæmia, the entrance of sodic chloride from the blood is, of course, enormous, and sodic chloride passes from *blood to gut* in the denuded loop, but from *gut to blood* in the normal. The following experiment is a striking example.

EXPERIMENT XXIX.—Dog, 17·5 kilos. Two 49 centims. Loops of Ileum. Duration of experiment, 15 minutes. One loop was denuded of epithelium by anæmia of its vessels for 30 minutes previous to experiment.

Introduced into each loop 30 cub. centims. of ·3 per cent. solution of sodic chloride, *i.e.*, ·09 grm. NaCl.

WATER.

	Recovered.	Absorbed.	Absorbed in per cent. of introduced.
	cub. centims.	cub. centims.	per cent.
Loop denuded of epithelium .	26	4	13·34
Normal loop.	3·5	26·5	88·34

SODIC CHLORIDE.

Loop denuded of epithelium . . . . . Contents held ·169 grm. NaCl (·65 per cent.), *i.e.*, *added* ·079 grm., NaCl = 87·7 per cent.

Normal loop . . . . . Contents held ·023 grm. NaCl (·66 per cent.), *i.e.*, *absorbed* ·067 grm. NaCl = 74·4 per cent.

The reduction of water absorption in the loop denuded of much epithelium is here evidently due to the fact that the blood salt pours into the gut lumen when the epithelial barrier is removed, while on the normal side both water and salt are rapidly absorbed by the blood.

Often the entrance of sodic chloride (and presumably of other blood salts) is so rapid, as a result of denudation of epithelium, that absorption of water from a previously hypotonic solution is absolutely stopped.

The following experiment, XXX., is an example of this :

EXPERIMENT XXX.—Dog, 17 kilos. Two 47 centims. Loops of Ileum. Duration of experiment, 15 minutes. One loop denuded of epithelium by 30 minutes' anæmia of its vessels previous to experiment.

Introduced into each loop 30 cub. centims. of 2 per cent. glucose solution in distilled water.

WATER ABSORBED.

	Recovered.	Absorbed.	Absorbed in per cent. of introduced.
	cub. centims.	cub. centims.	per cent.
Loop denuded of epithelium .	30	0	0
Normal loop	10·5	19·5	65

SODIC CHLORIDE ADDED.

Loop denuded of epithelium. . . ·1211 grm., giving concentration in fluid in gut of ·403 per cent.
Normal loop . . . . . ·0043 „ „ „ „ ·041 „

GLUCOSE ABSORBED.

Loop denuded of epithelium. . . ·1995 grm. (33·5 per cent. of quantity introduced). Concentration in gut fluid, ·66 per cent.
Normal loop . . . . . ·2370 grm. (39·5 per cent. of quantity introduced). Concentration in gut fluid, 3·45 per cent.

The last three experiments are then in every respect confirmatory of the results of O. COHNHEIM, already mentioned in the introduction to this paper, and with him I consider the small amount of sodium chloride entering the fluid introduced into normal loops of intestine in cases where the fluid selected has no injurious action upon the epithelium, as originating in the *succus entericus*.

But if, as COHNHEIM'S and my own experiments seem to show, the uptake of water from solutions in the gut is due largely to the partial osmotic pressure of the blood salts, and especially to sodium chloride, the one-sided permeability of the gut membrane to sodium chloride, upon which the explanation is based, has yet to be accounted for. The gut membrane obviously lets sodium chloride pass easily enough in the direction from the gut lumen to the blood, but very efficiently bars its passage in the reverse direction.

I believe it is safe to say that no inert physical membrane has yet been found in which such a condition of "molecule valves" exists.

True it is that membranes are known which allow filtration to take place more easily in one direction than in the other, as for instance the shell membrane of the hen's egg, but channels are here opened or shut by excess of hydrostatic pressure on one side or the other, and a diffusion experiment with sodic chloride solution into water in the two directions at equality of hydrostatic pressure on the two sides of the membrane, gave me an exactly equal diffusion in the two directions with pieces of egg shell membrane giving the ordinary difference in filtration resistance in the two directions. (From 10 cub. centims. of 2 per cent. NaCl solution, ·048 grm. NaCl diffused

in the in-out direction in 3 hours into 30 cub. centims. of H_2O, and ·048 in another piece of the same membrane in the out-in direction.)

It is, in fact, difficult to avoid as a working hypothesis the conclusion that some *mechanism* is in action in the living cells (not in the cement as HÖBER supposes) which can be crippled by injury to the cells, a mechanism which tends to drive the blood salts back as fast as they tend to diffuse into a bland solution lying in the gut, a mechanism which furthermore will forward into the blood any salt entering the cells from the gut side.

(2.) *Absorption of Distilled Water and Normal Saline Solution.*

The old question, therefore, whether water or "normal saline" solution is absorbed the faster from the gut depends to some considerable extent upon the condition of the epithelium at the time of the experiment, and so the extent to which its functional activity is depressed by the action of the water.

Two experiments, XXXIA and B, are here quoted, in one of which water is absorbed faster than normal saline solution, and in the other slower, but in the latter case the loop employed for the absorption of water had been washed with distilled water, and the condition of the cells thereby lowered, though no epithelium was detached, while in the former case both loops had been washed with normal saline solution.

EXPERIMENT XXXIA.—Dog, 17 kilos. Two 80 centims. Loops of Ileum. Duration of experiment, 20 minutes. *One loop washed with distilled water* (no detachment of epithelium). The other loop washed with normal saline solution (·9 per cent.). 50 cub. centims. fluid introduced into each loop.

	From distilled water in water washed loop.	From normal saline in saline washed loop.
Water absorption	24 cub. centims., *i.e.*, 48 per cent.	30 cub. centims., *i.e.*, 60 per cent.

HYDROSTATIC PRESSURES.

Water loop . . . . . 6 to 10 millims. of Hg.
Saline loop . . . . . 6 to 10 „ „

EXPERIMENT XXXIB.—Dog, 15 kilos. Two 80 centims. Loops of Ileum. Duration of experiment, 20 minutes. *Both loops washed with normal saline solution* (·9 per cent.). 50 cub. centims. fluid introduced into each loop.

	From distilled water in normal saline washed loop.	From normal saline in saline washed loop.
Water absorption	36 cub. centims., *i.e.*, 72 per cent.	28 cub. centims., *i.e.*, 56 per cent.

HYDROSTATIC PRESSURES.

Water loop	5 to 8 millims. of Hg.
Saline loop	5 to 8 „ „

At the same time the relation of the osmotic pressure in the solution in the gut to that of the blood, *cæteris paribus*, undoubtedly affects the rapidity of absorption of water from the solution, even when the salt in solution is sodium chloride, to which the gut membrane is so permeable in the direction from the gut to the blood, and it is a common laboratory practice to salt glucose solutions, if it is desired to prolong the experiment but still have sufficient fluid left in the gut for analysis (see some of the experiments in Table XII., p. 277).

My own thought leads me to imagine the presumably inert cement substance between the cells as being somewhat impermeable to substances in solution, though easily permeable by water, while the cells, by virtue of their mechanism, allow substances in solution and water to pass in the direction from the gut to the blood, provided the mechanism is in no way injured. The addition of salt to a fluid in the gut would then delay the absorption of water from it until such time as the cells had reduced the osmotic pressure by removal of salt.

Such a theory introduces the idea of cell action instead of the simpler one that the excess of salt *diffuses* over into the blood, and that the solution is then taken up by the partial osmotic pressure of substances in solution in the blood, to which the gut wall is impermeable.

But the evidence of an orienting action in the gut membrane is so distinct that it is, I believe, not permissible to treat it as an ordinary diffusion membrane, seeing that no inert diffusion membrane is yet imaginable with a " molecule valve " action.

THE ABSORPTION OF GLUCOSE AND PEPTONE IN THE ILEUM.

Probable Difference of Process in the two cases.

Turning now to the question of the absorption of glucose and peptone in solution in the gut, a few elementary considerations will indicate that the problem as to whether the absorption of these substances is or is not explicable upon physical grounds is one beset with great difficulty.

In the first place, since we are employing substances other than those imbibed by the cells continually from the blood plasma, the possibility of *adsorption* (as in the " absorption " of pepsin by fibrin) is before us.

Secondly, all the evidence we possess tends to show that a special accessory process is involved in the one case and not in the other. Peptone does not appear to enter the blood as such, while glucose does, so that no experimental comparison of the

rates of absorption of the two substances with their rates of diffusion through a parchment membrane into serum, will help to decide the question.*

An "assimilation" (possibly preceded by *adsorption*) must precede the final absorption of peptone, though this is not necessarily the case with glucose.

If peptone becomes a kind of serum albumin, as some have maintained, within the epithelial cells of the gut, it is obvious that the conditions for its diffusion must here abruptly end.

Thirdly, if in the case of glucose it is assumed that absorption is mere diffusion, since the absolute amount of a substance diffusing in a given time depends upon its concentration in the solution in the gut in relation to that of the same solution in the blood, it is evident that any condition delaying the absorption of water from the solution will, by tending to keep down the concentration of the solution in the gut, indirectly affect the loss from the gut by diffusion, *i.e.*, reduce the absorption.

This point at once becomes evident when we compare the absorption of glucose from a solution in a loop with normal epithelium against one the epithelium of which has been injured or partially removed. *Vide* Table XII., p. 277.

With reference to *adsorption*, no one who has read the work of HOFMEISTER and SPIRO can deny that the possibility of such action must be kept in mind, but it is of course impossible to deduce the phenomena with living or dead epithelial cells from the results of experiments with discs of gelatine. I cannot see at present how we are to separate *adsorptive* from assimilative phenomena when experiments deal with living protoplasm, since our knowledge of the physical and chemical conditions of this complex is so slight.

It has occurred to me that by reducing the conditions for diffusion in one loop of gut, and then comparing the uptake of peptone and glucose with that obtaining with the full conditions in a normal loop of gut, some light may be thrown upon the parts played respectively by diffusion on the one hand and *adsorption* or assimilation on the other in the cases of the absorption of peptone and glucose.

In the following two experiments, XXXIIA and B, the circulation of blood was stopped during the stay of the solution in the gut, in the case of one loop, while in the other loop the normal condition obtained. In both experiments the animals were in good condition, and no loss of epithelium resulted from the clamping of the vessels.

* In a previous paper ('Journal of Physiology,' 20, 1896, p. 307, Table V.) I have given evidence against regarding the absorption of peptone as a diffusion into the blood, and have also shown ('Jour. Phys.,' 21, 1897, p. 422, Table IV.) that commercial peptones of different diffusibility are absorbed at the same rate.

EXPERIMENT XXXIIA.—Absorption of *peptone* (in 2 per cent. solution in water). Dog, 12·5 kilos. Two 50 centims. Loops of Ileum. Duration of experiment, 15 minutes. Vessels of one loop clamped immediately before introduction of peptone solution. 30 cub. centims. of 2 per cent. peptone solution introduced into each loop.

	Normal loop.	Loop with clamped vessels.
Absorbed: Water . . .	15 cub. centims., *i.e.*, 50·00 per cent.	4·5 cub. centims., *i.e.*, 15·00 per cent.
„ Peptone . .	·2502 grm., . „ 41·7 „	·2091 grm., . . „ 34·85 „
Final concentration of peptone in fluid recovered from gut . .	2·33 per cent.	1·53 per cent.

EXPERIMENT XXXIIB.—Absorption of *glucose* (in 2 per cent. solution in water). Dog, 14·5 kilos. Two 50 centims. Loops of Ileum. Duration of experiment, 15 minutes. Vessels of one loop clamped immediately before introduction of glucose solution. 30 cub. centims. of 2 per cent. glucose solution introduced into each loop.

	Normal loop.	Loop with clamped vessels.
Absorbed: Water . . .	20 cub. centims., *i.e.*, 66·67 per cent.	7 cub. centims., *i.e.*, 23·34 per cent.
„ Glucose . .	·2464 grm., . „ 41·06 „	·1200 grm., . „ 20·00 „
Final concentration of glucose in fluid recovered from gut . .	3·536 per cent.	2·09 per cent.

It would appear that the reduction of the conditions for diffusion by clamping the vessels reduces the absorption of peptone below the normal level considerably less than it reduces the absorption of glucose, from which I must conclude that the process of *adsorption* or assimilation is of greater moment in the absorption of peptone than of glucose.

I find that poisoning the gut wall with atropine reduces the absorption of peptone below the normal level, but one cannot conclude directly that this is due to reduced assimilative action as a result of lessened protoplasmic activity, because it is always possible that some compound of a cell constituent with atropine possesses a less mechanical or chemical affinity for peptone than is possessed by the same constituent in its native state. The experiments are, however, suggestive of lowering of cell action, and so of assimilation, especially as the blood circulation in the loop poisoned with atropine is increased.

The experiments are contained in Table X.

TABLE X.—Action of Atropine on Absorption of Peptone and Water. Duration of experiment, 15 minutes. Length of Gut Loops, 30 centims. 30 cub. centims. of 2 per cent. Peptone Solution introduced. Absorptions are quoted in per cent. of matter introduced.

Normal loop.			Atropinised loop.			Atropine sulphate in loop.
Water.	Peptone.	Ratio.	Water.	Peptone.	Ratio.	
						milligrms.
66·67	53·53	1·24	56·67	39·77	1·42	10
66·67	50·70	1·31	51·00	37·52	1·36	20
73·34	65·37	1·12	63·34	56·35	1·12	40
71·67	47·33	1·51	68·34	41·47	1·65	10

In three of the cases the absorption of peptone is relatively more reduced than that of water.

Effects of Removal of Epithelium.

If the conclusion be correct that the *adsorptive* or assimilative factor is of greater moment in the absorption of peptone than of glucose, we shall expect to find that removal of the intestinal epithelium will be more unfavourable to the absorption of peptone than to that of glucose.

Such appears to be the case so far as my experiments have gone. In the two experiments quoted in Table XI. the absolute absorption of peptone is diminished by removal of the epithelium in both cases, but in the first it is actually less in proportion to the final concentration of peptone in the loop.

TABLE XI.—Effect of Removal of Epithelium on Absorption of Peptone. In all cases the Concentration of the Peptone Solution introduced was 2 per cent. Denudation of Epithelium by previous Anæmia for 30 minutes.

Number of experiment.	Weight of dog in kilos.	Length of loops of ileum in centims.	Duration of experiment in minutes.	Number of cub. centims. of 2 per cent. solution of peptone introduced into each loop.	Loop.	Absorbed.				Concentration in peptone of solution in gut at end of experiment.
						Peptone.		Water.		
						grm.	per cent.	cub. centims.	per cent.	per cent.
I.	15	60	15	30	Normal	·3713	61·88	18·5	61·67	1·99
					Denuded	·1637	27·28	1·0	3·34	1·5
II.	14	60	20	40	Normal	·5021	62·76	33·0	82·5	4·25
					Denuded	·3271	40·88	17·0	42·5	2·05

In Experiment I. the absorption of peptone is less in proportion to the final concentration in the denuded loop than in the normal loop; in Experiment II. it is greater.

Passing to glucose I find that sometimes the absolute absorption is increased by removal of the epithelium, but that in all cases the absorption is greater in proportion to the final concentration of glucose in the loop, as seen in Table XII.

TABLE XII.—Effect of Removal of Epithelium upon Absorption of Glucose. In all cases the Concentration of the Glucose Solution introduced into Gut was 2 per cent. Denudation of Epithelium by previous Anæmia for 30 minutes.

Number of experiment.	Weight of dog in kilos.	Length of loops of ileum in centims.	Duration of experiment in minutes.	Number of cub. centims. of 2 per cent. solution of glucose introduced into each loop.	Loop.	Absorbed.				Concentration in glucose of solution in gut at end of experiment.
						Glucose.		Water.		
						grm.	per cent.	cub. centims.	per cent.	per cent.
I.	9·5	35	15	30	Normal	·1476	24·6	10	33	2·262
					Denuded	·1392	23·2	0	0	1·486
II.	7	46	15	40	Normal	·1232	15·4	14	35	2·60
					Denuded	·1076	13·45	0	0	1·24
III.	14	50	30	30	Normal	·1908	31·8	11·5	38·34	2·21
					Denuded	·3034	51·4	0	0	·97
IV.	9	40	30	30	Normal	·1986	33·2	8	26·67	1·82
					Denuded	·1854	30·9	1	3·34	1·43
V.	14	41	30	30	Normal	·1640	27·34	11·5	38·34	2·35
					Denuded	·2630	48·83	0	0	1·12
VI.	17	47	15	30	Normal	·2370	39·5	19·5	65·0	3·45
					Denuded	·1995	33·5	0	0	·66

In Experiments I., II., and VI., the glucose was in solution in distilled water.
In Experiments III., IV., and V., the glucose was in solution in ·6 per cent. solution of sodic chloride.

In Experiments III. and V. in this table the absolute absorption of glucose is greater in the denuded loop than in the normal.

Comparison of Absorption with Dialysis into Serum.

It is next necessary to compare in denuded loops of gut, in one and the same animal, the rapidities of absorption of glucose and peptone.

I have shown in a previous paper that the normal rapidities of absorption in a loop clad with epithelium are, as one would expect, quite different to the rates of diffusion into stirred and changed serum.

Can one expect to find the diffusion ratios maintained when denuded loops of gut are used instead of parchment tubes? Probably not, for the simple reason that the membrane is different, but nevertheless one does expect that glucose will disappear rather faster than peptone, though the ratio of its absorption to that of peptone will probably be different to the diffusion ratio and variable on account of the impossibility of securing that the vascularity and degree of denudation of epithelium in two experimental loops of gut shall be identical.

In the following table, XIII., are included some results with a pair of denuded loops.

TABLE XIII.—Absorption of Glucose and Peptone in *Denuded Loops of Gut* in one and the same Animal. In all cases the Concentration of the Glucose and Peptone Solutions used was originally 2 per cent. Denudation of Epithelium by previous Anæmia for 30 minutes.

Number of experiment.	Weight of dog in kilos.	Length of loops of ileum in cub. centims.	Duration of experiment in minutes.	Number of cub. centims. of solution of glucose or peptone introduced into each loop.	Absorbed.				Final concentration of solution in loops.	
					Glucose loop.		Peptone loop.			
					Glucose.	Water.	Peptone.	Water.	Glucose.	Peptone.
I.	17·5	46	15	30	·2488 grm. = 42·20 per cent.	7 cub. centims. = 23·34 per cent.	·1736 grm. = 28·93 per cent.	4 cub. centims. = 13·34 per cent.	per cent. 1·53	per cent. 1·64
II.	...	40	15	30	·2376 grm. = 39·60 per cent.	3·5 cub. centims. = 11·67 per cent.	·1272 grm. = 21·2 per cent.	1 cub. centim. = 3·34 per cent.	1·36	1·63
III.	15	40	15	30	·1304 grm. = 21·73 per cent.	1·5 cub. centims. = 5·00 per cent.	·1408 grm. = 23·46 per cent.	*Added* 1 cub. centim. = 3·34 per cent.	1·64	1·48
IV.	14	50	15	30	·2745 grm. = 45·75 per cent.	2·0 cub. centims. = 6·67 per cent.	·2255 grm. = 37·58 per cent.	0 cub. centim. = 0 per cent.	1·16	1·24

	Per cent. glucose absorbed / Per cent. peptone absorbed
Experiment I. . . .	1·45
„ II. . . .	1·87
„ III. . . .	·92
„ IV. . . .	1·21

NOTE.—In Experiment III. the loss of epithelium was slight.

In three of the experiments quoted in this table (XIII.) the absorption of glucose is in excess of that of peptone, but a comparison with the subjoined tables (XIV. and XV., pp. 279 and 280), taken from a previous paper, indicates that, while the ratio of glucose absorption to peptone absorption in denuded loops does not reach the magnitude found for diffusions through parchment paper into stirred and changed serum, yet it is well in excess of the ratio in normal epithelium-clad loops. Experiment III. in Table XIII. gave practically a normal result, but the loss of epithelium in this case was distinctly less than usual.

TABLE XIV.*

Preliminary tests.							Experiments.							
Trial of permeability of dialyser tubes by diffusion of 125 cub. centims. of 1 per cent. glucose solution into 125 cub. centims. of stirred water at 38° C. for 2 hrs. Surface of parchment paper, 157·4 sq. centims.							Diffusion of 125 cub. centims. of 2 per cent. glucose and 2 per cent. GRÜBLER'S peptone solution into 125 cub. centims. of stirred ox serum, holding ·1 per cent. of added glucose at 38° C., for 6 hours with hourly renewal of sugared serum. Surface of parchment paper, 157·4 sq. centims.							
No. of experiment.	Dialyser tube.	Milligrms. of copper reduced by $\frac{1}{1\frac{1}{2}}$ final volume of glucose solution.	Milligrms. of glucose in $\frac{1}{1\frac{1}{2}}$ final volume of glucose solution.	Weight of glucose left (grm.).	Weight of glucose diffused (grm.).	Per cent. weight of glucose diffused.	Substance diffused.	Milligrms. of copper reduced by $\frac{1}{10}$ final vol. of glucose solution (A), or cub. centims. of N/2 sulphuric acid neutralised in Kjeldahl estimation of phosphotungstic precipitate of $\frac{1}{8}$ final vol. of peptone solution (B).	Glucose (A) or peptone (B) left in solution (grms.).	Glucose (A) or peptone (B) diffused (grm.).	Water absorbed cub. centims.	Per cent. weight of glucose (A) or peptone (B) diffused.	Per cent. water absorbed.	Ratio $\frac{\text{Per cent. glucose diffused}}{\text{Per cent. GRÜBLER'S peptone diffused}}$
(1)	A	170·3, 169·3 } 170·0	86·9	1·0428	·2072	16·57	Glucose	151·0, 150·0 } 150·5	1·5350	·965	3·0	38·60	2·40	2·40
	B	168·4	86·1	1·0332	·2168	17·34	GRÜBLER'S peptone	6·4	2·099	·401	3·4	16·04	2·72	
(2)	A	168·6, 169·2 } 168·9	86·4	1·0368	·2132	17·05	Glucose	149·6	1·5260	·974	2·2	39·00	1·76	2·19
	B	167·4, 167·8 } 167·6	85·6	1·0272	·2228	17·82	GRÜBLER'S peptone	6·22, 6·33 } 6·27	2·056	·444	2·8	17·76	2·24	
(3)	A	169·8	86·8	1·0416	·2084	16·67	Glucose	153·3, 153·5 } 153·4	1·5660	·934	2·6	37·36	2·08	2·16
	B	170·8, 171·2 } 171·0	87·4	1·0488	·2012	16·08	GRÜBLER'S peptone	6·31	2·069	·431	3·0	17·24	2·40	
(4)	A	...	...	...	...	...	Glucose	153·4, 152·6 } 153·0	1·5620	·938	2·0	37·52	1·60	1·99
	B	...	...	...	...	...	GRÜBLER'S peptone	6·08, 6·30 } 6·19	2·030	·470	2·8	18·80	2·24	
(5)	A	167·0, 167·4 } 167·2	85·4	1·0248	·2252	18·01	Glucose	148·7, 148·3 } 148·5	1·5150	·985	2·6	39·40	2·08	2·55
	B	168·0, 167·2 } 167·6	85·6	1·0272	·2228	17·82	GRÜBLER'S peptone	6·66, 6·24 } 6·45	2·115	·385	3·0	15·40	2·40	

Mean ratio from the five experiments, 2·26.

* From the 'Journal of Physiology,' vol. 21, 1897, p. 417.

TABLE XV.*—Intestinal Absorption of Glucose and GRÜBLER'S Peptone. Time of Experiment in all cases, 15 minutes.

No. of experiment.	Weight of dog (kilos.).	Length of loops (centims.).	Surface (sq. centims.).	Peptone or glucose introduced into each loop (grm.).	Water introduced into each loop (cub. centims.).	Glucose or peptone absorbed (grm.).		Water absorbed (cub. centims.).		Per cent. glucose or peptone absorbed.		Per cent. water absorbed.		Ratio Per cent. glucose absorbed / Per cent. peptone absorbed.
						Glucose.	Peptone.	Glucose loop.	Peptone loop.	Glucose.	Peptone.	Glucose loop.	Peptone loop.	
I.	20	52	286	1·0	50	·3568	·34020	27·0	31·0	35·68	34·02	54·00	62·00	1·04
II.	16·5	30	125	·6	30	·3414	·29800	19·5	20·0	56·90	49·67	65·00	66·67	1·14
III.	26·5	40	236	·6	30	·3024	·37203	21·5	21·0	50·40	62·00	71·67	70·00	·81
IV.	23	40	256	·6	30	·2120	·27034	17·0	19·0	35·34	45·06	56·67	63·34	·78
V.	16·5	39	200	·6	30	·2136	·27855	17·5	17·5	35·6	46·42	58·34	58·34	·77
VI.	20	40	...	·6	30	·2340	·28948	18·5	16·5	39·00	48·25	61·67	55·00	·80
VII.	20	40	...	·6	30	·2400	·27636	18·0	18·0	40·00	46·06	60·00	60·00	·87

Mean ratio from the seven experiments, ·89.

The point on the gut from which the loops were measured off upwards was in Experiments I., III., IV., and VI., 155 centims. from the ileo-cæcal valve; in II. it was 125 centims., in V. it was 100 centims., and in VII. it was 130 centims.

In Experiments VI. and VII. a preliminary soakage of the loops in the solution to be absorbed had taken place.

* From the 'Journal of Physiology,' vol. 21, 1897, p. 421.

My present view, then, is that in the normal gut the absorption of peptone is in the main a matter of *adsorption* or assimilation, while, though a similar process may occur to some extent in absorptions of glucose, nevertheless diffusion is an important factor.

ABSORPTION OF GLUCOSE AND PEPTONE IN DIFFERENT REGIONS OF THE INTESTINE.

A. Glucose.

Absorption in Upper and Lower Ileum.

Since Lannois and Lépine found that the absorption of glucose in the lower region of the ileum, near the cæcum, was far behind that in the upper reaches, it has been considered by many that this definitely proves some specific activity of the gut epithelium in the absorption of sugar, since the conditions for diffusion are quite as good if not better (from greater vascularity) in the lower ileum than in the upper.

I have repeated the experiments of Lannois and Lépine on the point, and can substantiate their statement. My results are to be found in Table XVI., p. 283.

In all the experiments in this table the absorptions of glucose in the lower ileum are less than in the upper. Experiment IV. is very convincing on the point, since the absorption of water in the two loops is identical, though the absorption of glucose was only 23·73 per cent. in the lower loop as against 41·34 per cent. in the upper.

Effect of Removal of Epithelium.

That the difference in absorption is associated with the *presence* of the epithelium is evident if one removes the epithelium by previous anæmia, as was done in the two examples in Table XVII., p. 284. Here it is evident that the absorption of glucose in the lower loop rather exceeds that in the upper, probably because the lower loop is the more vascular of the two.

There is, it must be remembered, an anatomical difference between the mucosa of the lowest part of the ileum and the upper regions, viz., the goblet cells of the villi are more numerous in the lower than in the upper.

These goblet cells may be less permeable to sugar in solution than the cylinder cells, and whether one takes the view that the sugar diffuses into the blood through the bodies of the cells, or is actively taken up by the cells, it is probable that the difference in absorption is associated with the difference in the number of cylinder cells to the unit of absorbing surface, rather than to any specialised activity of those in the upper regions.

I do not, then, see that the fact proves anything *qua* active absorption.

Absorption in Ileum and Colon.

The absorption of glucose in the colon bears the same relation to that in the upper ileum, as does the absorption in the lower ileum to the same region.

The surfaces in the case of colon and ileum as measured by a gelatine cast are, of course, not comparable as in the case of an upper and lower loop of ileum itself, on

account of the absence of villous extension of surface in the case of the colon, but, as in the ileum experiments in Table XVI., p. 283, so here, in proportion to water the absorption of glucose is much less in the colon than in the ileum, even when, as in Experiment III. in the subjoined Table XVIII., p. 285, the loops of ileum and colon are taken immediately on either side of the cæcum.

B. Peptone.

Absorption in Upper and Lower Ileum.

If we now compare the absorption of peptone in the upper and lower reaches of the ileum, practically the same result is obtained as with glucose.

This comparison was made with similar results by Lannois and Lépine, but their method of estimating peptone was not free from error.

The absorption of peptone, as seen in Table XIX., p. 286, is absolutely less in the lower than in the upper regions, and less in proportion to the water absorption.

Absorption in Ileum and Colon.

With the colon, though the absolute absorption of peptone is much less than in the ileum, yet, in proportion to the water absorption, the absorption of peptone is greater, as a rule, than in the ileum, and so stands in contrast in this latter point to glucose in ileum and colon. The results with peptone in ileum and colon are included in the next table (XX., p. 287).

Obviously, if in comparisons of colon and ileum one estimated the gut surface by the help of a "villus factor" in the case of the ileum and not in the case of the colon, since this factor was estimated by Heidenhain at 23, and by Mall at 15·4, the absorptions of glucose and peptone in the colon per square unit will far exceed those in the ileum, but it is equally obvious that no such procedure is permissible, because we neither know to what extent the surface of the villi is employed in an absorption experiment, nor do we know whether the absorption by the mucosa of the colon is absolutely restricted to the surface between the mouths of the crypts, such as we measure by a cast.

Absorption of Water in Ileum and Colon.

Finally, in this connection, as regards the absorption of water in the ileum and colon, I find, as did Edkins (though in his experiment absorptions in different animals were compared) that per unit of measured surface the absorption of water by the colon is less than in the ileum, and that this result is not related to any excessive entrance of blood salts into the fluid in the colon is indicated by the fact that the lowering of freezing point of the fluid removed at the end of the experiment is practically identical in the case of ileum and colon. Here again the employment of a "villus" factor in the case of the ileum would reverse the conclusion, but, as stated already, such a procedure is not admissible.

Two experiments upon absorption of water in ileum and colon are included in Table XXI., p. 288.

TABLE XVI.—Comparisons of Absorptions of *Glucose* in Upper and Lower Regions of *Ileum*. In all cases the Lower Loop commences at the Ileo-cæcal Valve. Glucose Solution, 2 per cent. in Water in Experiment I., in ·6 per cent. NaCl in Experiments II., III., and IV.

Number of experiment.	Weight of dog in kilos.	Duration of experiment in minutes.	Volume of solution introduced into each loop in cub. centims.	Distance of upper loop from ileo-cæcal valve in centims.	Length of loops in centims.	Surface of loops in sq. centims.	Final concentration of glucose in fluid recovered per cent.	Absorptions.			
								Upper loop.		Lower loop.	
								Glucose.	Water.	Glucose.	Water.
I.	22	15	50	230	Upper 80 Lower 80	... ...	2·73 3·24	·4948 grm. =49·48 per cent.	31·5 cub. centims. =63·00 per cent.	·3676 grm. =36·76 per cent.	30·5 cub. centims. =61·00 per cent.
II.	17	15	30	230	Upper 50 Lower 50	... ...	2·04 2·52	·1608 grm. =26·80 per cent.	8·5 cub. centims. =28·34 per cent.	·0060 grm. =1·00 per cent.*	6·5 cub. centims. =21·67 per cent.
III.	19	30	40	210	Upper 60 Lower 60	336 330	1·80 2·42	·4704 grm. =58·80 per cent.	22 cub. centims. =55·00 per cent.	·2192 grm. =27·40 per cent.	16 cub. centims. =40·00 per cent.
IV.	18	30	30	170	Upper 50 Lower 50	275 265	1·95 2·54	·2480 grm. =41·34 per cent.	12 cub. centims. =40·00 per cent.	·1424 grm. =23·73 per cent.	12 cub. centims. =40·00 per cent.

	Per cent. water absorbed / Per cent. glucose absorbed	
	Upper loop.	Lower loop.
Experiment I.	1·27	1·65
„ II.	1·05	21·67
„ III.	·93	1·46
„ IV.	·96	1·68

* LANNOIS and LÉPINE quote one experiment (No. XXII. in their paper) in which there was no absorption of glucose in the lower ileum in 15 minutes, while 56 per cent. of the introduced glucose was absorbed in a loop of upper ileum. The glucose in their experiment was in solution in urine.

TABLE XVII.—Comparisons of Absorptions of *Glucose* in *Denuded* Upper and Lower Loops of *Ileum*. In both cases the Lower Loop commences at the Ileo-cæcal Valve. Glucose Solution, 2 per cent. in ·6 per cent. Solution of NaCl.

Number of experiment.	Weight of dog in kilos.	Duration of experiment in minutes.	Volume of solution introduced into each loop in cub. centims.	Distance of upper loop from ileo-cæcal valve in centims.	Length of loops in centims.	Surface of loops in sq. centims.	Final concentration of glucose in fluid recovered per cent.	Absorptions.			
								Upper loop.		Lower loop.	
								Glucose.	Water.	Glucose.	Water.
I.	13·5	30	30	125	Upper 47 Lower 50	258 245	1·00 1·08	·4328 grm. = 72·13 per cent.	13·5 cub. centims. = 45·00 per cent.	·4536 grm. = 75·60 per cent.	16·5 cub. centims. = 55·00 per cent.
II.	13·5	30	30	125	Upper 47 Lower 50	240 250	1·59 1·38	·2024 grm. = 33·73 per cent.	5 cub. centims. = 16·67 per cent.	·2544 grm. = 42·40 per cent.	5 cub. centims. = 16·67 per cent.

NOTE.—In Experiment II. the lower loop was distinctly more hyperæmic than the upper.

TABLE XVIII.—Comparisons of Absorptions of *Glucose* in *Ileum* and *Colon*. Glucose Solution, 2 per cent. in ·6 per cent. Solution of NaCl.

Number of experiment.	Weight of dog in kilos.	Duration of experiment in minutes.	Volume of solution introduced into each loop in cub. centims.	Distance of loop of ileum from ileo-cæcal valve in centims.	Length of loops in in centims.	Surface of loops in sq. centims.	Final concentration of glucose in fluid recovered per cent.	Absorptions.			
								Ileum.		Colon.	
								Glucose.	Water.	Glucose.	Water.
I.	14	30	25	100	Ileum 25 Colon 17	120 147	2·67 2·28	·2728 grm. =54·56 per cent.	16·5 cub. centims. =66·00 per cent.	·0216 grm. =4·32 per cent.	4 cub. centims. =16·00 per cent.
II.	14	30	30	100	Ileum 36 Colon 23	169 174	3·09 2·07	·2448 grm. =40·80 per cent.	18·5 cub. centims. =61·67 per cent.	·0416 grm. =6·93 per cent.	3 cub. centims. =10·00 per cent.
III.	15	30	30	0	Ileum 38 Colon 22	186 176	2·57 2·35	·1872 grm. =31·20 per cent.	14 cub. centims. =46·67 per cent.	·0456 grm. =7·60 per cent.	6·5 cub. centims. =21·67 per cent.

	Per cent. water absorbed / Per cent. glucose absorbed	
	Ileum.	Colon.
Experiment I.	1·21	3·70
„ II.	1·51	1·44
„ III.	1·49	2·85

NOTE.—In Experiment III. the *lower* ileum is compared with the colon, the loops being selected immediately on either side of the cæcum.

TABLE XIX.—Comparisons of Absorptions of *Peptone* in Upper and Lower Regions of *Ileum*. In all cases the Lower Loop commences at the Ileo-cæcal Valve. Peptone Solution, 2 per cent. in Water.

Number of experiment.	Weight of dog in kilos.	Duration of experiment in minutes.	Volume of solution introduced into each loop in cub. centims.	Distance of upper loop from ileo-cæcal valve in centims.	Length of loops in centims.	Surface of loops in sq. centims.	Final concentration of peptone in fluid recovered per cent.	Absorptions			
								Upper loop.		Lower loop.	
								Peptone.	Water.	Peptone.	Water.
I.	17	15	40	230	Upper 60 Lower 60	... ...	3·5 3·16	·3627 grm. =45·33 per cent.	27·5 cub. centims. =68·75 per cent.	·2457 grm. =30·71 per cent.	22·5 cub. centims. =56·25 per cent.
II.	17·5	15	40	230	Upper 60 Lower 60	342 318	2·12 2·29	·2041 grm. =25·51 per cent.	12 cub. centims. =30·00 per cent.	·1795 grm. =22·43 per cent.	13 cub. centims. =32·5 per cent.
III.	19	15	40	230	Upper 60 Lower 60	345 330	2·46 2·43	·3326 grm. =41·57 per cent.	21 cub. centims. =52·50 per cent.	·1795 grm. =22·43 per cent.	14·5 cub. centims. =36·25 per cent.

	$\frac{\text{Per cent. water absorbed}}{\text{Per cent. peptone absorbed}}$.	
	Upper loop.	Lower loop.
Experiment I.	1·51	1·83
„ II.	1·17	1·44
„ III.	1·26	1·61

TABLE XX.—Comparisons of Absorptions of *Peptone* in *Ileum* and *Colon*. Peptone Solution, 2 per cent. in Water.

Number of experiment.	Weight of dog in kilos.	Duration of experiment in minutes.	Volume of solution introduced into each loop in cub. centims.	Distance of loop of ileum from ileo-cæcal valve in centims.	Length of loops in centims.	Surface of loops in sq. centims.	Final concentration of peptone in fluid recovered per cent.	Absorptions.			
								Ileum.		Colon.	
								Peptone.	Water.	Peptone.	Water.
I.	13·5	15	30	100	Ileum 32·5 Colon 19·5	162 163	2·10 2·07	·1791 grm. =29·85 per cent.	10 cub. centims. =33·34 per cent.	·0615 grm. =10·25 per cent.	4 cub. centims. =13·34 per cent.
II.	19	15	30	100	Ileum 37 Colon 22·5	188 175	2·83 2·00	·2037 grm. =33·09 per cent.	16 cub. centims. =53·34 per cent.	·1310 grm. =21·83 per cent.	6·5 cub. centims. =21·67 per cent.
III.	12·5	15	30	100	Ileum 35 Colon 21	185 168	2·38 2·10	·1709 grm. =28·48 per cent.	12 cub. centims. =40·00 per cent.	·0943 grm. =15·71 per cent.	6 cub. centims. =20·00 per cent.
IV.	12·5	15	40	100	Ileum 43 Colon 26	262 270	2·59 1·70	·3463 grm. =43·30 per cent.	22·5 cub. centims. =56·25 per cent.	·1866 grm. =23·32 per cent.	4 cub. centims. =10·00 per cent.

	Per cent. water absorbed / Per cent. peptone absorbed	
	Ileum.	Colon.
Experiment I.	1·12	1·30
„ II.	1·61	·99
„ III.	1·40	1·27
„ IV.	1·30	·43

TABLE XXI.—Comparisons of Absorptions of *Water* in *Ileum* and *Colon*. In Experiment I. Tap Water ($\Delta = -\cdot 015°$ C.) was used. In Experiment II. Distilled Water.

Number of experiment.	Weight of dog in kilos.	Duration of experiment in minutes.	Volume of water introduced in cub. centims.	Distance of loop of ileum from ileo-cæcal valve in centims.	Length of loops in centims.	Surface of loops in sq. centims.	Lowering of freezing point of fluid recovered from loop.	Water absorptions.			
								Ileum.		Colon.	
								Absolute.	Per sq. centim. per hour.	Absolute.	Per sq. centim. per hour.
							°C.				
I.	13	15	30	100	Ileum 32 Colon 19·5	181 166	−·155 −·155	16·5 cub. centims. = 55·00 per cent.	·3976	4·5 cub. centims. = 15·00 per cent.	·0992
II.	13	15	30	100	Ileum 35 Colon 21	192·5 187	−·130 −·135	10 cub. centims. = 33·34 per cent.	·2076	2·5 cub. centims. = 8·34 per cent.	·0532

NOTE.—EDKINS, using normal saline solution in cats, and comparing the absorptions in different individuals, got as average, absorptions per sq. centim. per hour of ·521 cub. centim. in ileum and ·330 cub. centim. in colon, but with considerable variations in the different experiments.

CONCLUSIONS.

1. A physiological activity of the intestinal epithelium in the act of absorption is demonstrated by:

   (*a*) The absorption by an animal of its own serum (or even plasma) under conditions in which filtration into blood capillaries or lacteals, osmosis, and *adsorption* are excluded.

   (*b*) By the cessation or diminution of the absorption of serum when the epithelium is removed, injured, or poisoned, in spite of the fact that removal, at any rate, must increase the facilities for osmosis and filtration.

2. The activity of the cells is characterised by a slower uptake of the organic solids of the serum than of the water, and a rather quicker uptake of the salts than of the water. The relations to one another of the absorptions of these various constituents is variable in different regions of the intestinal canal (upper ileum, lower ileum, and colon).

3. No evidence can be obtained of specific absorptive fibres in the mesenteric nerves.

4. The state of nutrition of the cells is the main factor in their activity, and this is intimately associated with the blood supply.

5. In reduction of the rate of absorption, without detachment of epithelium, the absorption of the various constituents of serum is reduced in the proportion in which they exist in the original fluid.

6. The activity of the cells may be raised by stimulation with weak alcohol without evidence of concomitant increase of blood supply.

7. The bile has not a stimulant action on the cells.

8. The cells exhibit an orienting action upon salts in solution (sodic chloride especially). In a loop of gut with injured cells sodic chloride enters the lumen from the blood, at a time when it is being actively absorbed from a normal control loop in the same animal. (This fact was first noted by O. COHNHEIM.)

9. The absorption of water from the gut is dependent upon two factors:

   (*a*) The physical relation of the osmotic pressure of the solution in the gut to the osmotic pressure of the blood plasma.

   (*b*) The physiological regulation of this difference by the orienting mechanism of the cells.

10. The chief factor in the absorption of peptone is an assimilation (or *adsorption*) by the cells, while in the absorption of glucose, diffusion, variable by the permeability of the cells (and so probably related to their physiological condition), is the main factor.

11. By removal of the epithelium, the normal ratio of peptone to glucose

absorption is upset, and the value tends to approach that of diffusion of these substances through parchment paper into serum.

12. Absorption in the lower ileum is greater for the organic solids of serum, and less for peptone and glucose than in the upper ileum. The relative absorption of water in the upper and lower ileum is variable.
13. The relative impermeability of the lower ileum to glucose disappears with removal of the epithelium.
14. Absorption in the colon is for all constituents of serum, and for peptone and glucose, far less per unit of measured surface than in the middle region of the ileum.
15. The normal relative excess of salt absorption from serum over water absorption, observed throughout the intestine, is most marked in the colon, and more marked in the lower than in the upper ileum.
16. Finally, it is suggested that the cell activity which causes serum to pass over to the blood is of the same nature as that involved in the orienting action of the cells upon salts in solution.

In conclusion I here wish to express my thanks to my colleagues Professors WALKER and KUENEN for much kind advice on matters chemical and physical, and to my assistant Mr. J. S. MACDONALD for much practical help in carrying out the experiments.

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[Note. October 19th, 1899.—In a recent paper ('Ztschr. für Biologie,' vol. 20, 1899, p. 418), O. COHNHEIM describes the transfer of fluids from the lumen of the exsected and surviving gut of the cat, to oxygenated blood or normal saline bathing the outside of the viscus. In various ways it is shown that osmosis, filtration, and imbibition can be excluded without stopping the main effect, and furthermore, that the presence of sodium fluoride causes cessation of the process.

This observer has unfortunately missed a paper by the author published more than seven years ago ('Brit. Med. Journal,' May 28th, 1892), in which a method of demonstration of "vital" transfer of normal saline solution to normal saline solution across exsected rabbits' gut at equality of hydrostatic pressure on the two sides of the membrane was described.

The method had one advantage over that of O. COHNHEIM, in that not only the absorption of fluid on the epithelial side, but the *output* on the serous side was made evident.]

APPENDIX.

Methods employed in the Experiments described in the foregoing pages.

Analysis of Sera.

A weighed quantity of the serum introduced into each loop of intestine, and of the sera removed from each loop (after centrifugalisation or filtration through glass wool for removal of *débris* of food, &c.) was analysed for the content in total solids and ash.

In the analysis for total solids, tared porcelain vessels holding dried purified sand were employed, the sand being used to obtain rapid drying. The sand in the dishes was soaked with serum, and the nett weight of serum noted, heated at 110° C. in an air oven for 20 to 24 hours, cooled for an hour in a desiccator, and the weight again taken. From the weighings the percentage of the total solids was calculated in the three samples of serum.

The estimation of salts was made in three other samples of the same sera, by weighing a quantity in a tared platinum capsule in each case, drying in the oven overnight, and then incinerating.

The incinerations were conducted over Argand lamps, with a slight draught through the capsule obtained by tilting the lid so as to obtain an inlet and outlet. By using the Argand burner turned down till it just does not smoke, a very safe temperature is obtained, and volatilisation of sodic chloride completely avoided. By this method it takes about 6 or 8 hours to obtain a residue, the weight of which does not decrease on further heating; no sign of red heat in the capsule is permitted.

(A gas regulator is advisable on the supply to the Argand burners, otherwise the sudden raising of the pressure at the gasworks on winter afternoons is liable to cause fusion of the ash before the carbon is completely oxidised, a result, of course, fatal to any further oxidation.)

By subtraction of the percentage of salts from the percentage of total solids, the percentage of organic solids was obtained.

In cases where substances were added to the sera (as in the bile experiments, p. 259) the ash and organic solids of the added substance was estimated and allowed for in the calculations. An example of an experiment quoted in full is appended to make the method clear.

EXPERIMENT I. in Table I., p. 228. Fully quoted.—Dog, 19 kilos. 400 cub. centims. of blood drawn and centrifugalised for serum. Two 80 centims. Loops of Ileum provided with cannulæ at each end, and washed with normal saline.

Introduced into each loop 50 cub. centims. of the serum warmed to 40° C.

Recovered after 40 minutes 27 cub. centims. from the upper loop, and 28·5 cub. centims. from the lower loop.

TOTAL SOLIDS OF THE SERA.

	Introduced serum.	Removed from upper loop.	Removed from lower loop.
Taken	10·2672 grms.	10·1735 grms.	10·1894 grms.
Dry weight	·7840 grm.	1·1104 grm.	1·0831 grm.
Per cent. total solids .	7·63 per cent.	10·91 per cent.	10·63 per cent.

ASH.

	Introduced serum.	Removed from upper loop.	Removed from lower loop.
Taken	10·3008 grms.	10·2194 grms.	9·9742 grms.
Weight of ash . . .	·0958 grm.	·0919 grm.	·0902 grm.
Per cent. salts . . .	·930 per cent.	·899 per cent.	·904 per cent.

SUMMARY.

	Organic solids.	Salts.
	grms.	grm.
Introduced 50 cub. centims. of own serum, holding	3·3500	·4650
Removed: Upper loop, 27 cub. centims. serum, holding	2·7030	·2427
„ Lower loop, 28·5 cub. centims. serum, holding	2·7719	·2576

ABSORBED DURING THE 40 MINUTES.

	Upper loop.	Lower loop.
Water . . .	23·00 cub. centims., *i.e.*, 46·00 per cent.	21·50 cub. centims., *i.e.*, 43·00 per cent.
Organic solids .	·6470 grm., . . „ 19·31 „	·5781 grm., . . „ 17·25 „
Salts	·2223 „ . . „ 47·80 „	·2074 „ . . „ 44·60 „

LOWERINGS OF FREEZING POINT.

Introduced serum.	Removed from upper loop.	Removed from lower loop.	Serum of dog at end of experiment.
– ·600° C.	– ·580° C.	– ·585° C.	– ·615° C.

Analysis of Peptone.

To the fluid directly recovered from the gut were added the boiled-down washings of the loop, and after addition of an equal volume of 10 per cent. trichloracetic acid, the mixture was raised to 80°–90° C. Any precipitate of added *succus proteids* was filtered off, a hot water funnel being used, the filtrate reduced in volume on the water bath, and the peptone precipitated by means of phospho-tungstic acid.

This precipitate was collected on a filter, washed with weak solution of phospho-tungstic acid holding sulphuric acid, and the nitrogen estimated by the Kjeldahl process, mercury, potassic sulphate and later potassic permanganate being used in the oxidation stage, and sodic sulphide, in addition to the hydrate, in the distillation. The distillation was into semi-normal sulphuric acid, and methyl orange was the indicator in the final titration.

From the nitrogen values the peptone was calculated by means of a factor, arrived at by estimations after the same method, of the sample of peptone used. One sample of commercial peptone has been used throughout; it had been prepared by HENNINGER'S method and was obtained from Dr. GRÜBLER.

For further details the reader is referred to a previous paper ('Journal of Physiology,' vol. 19, 1896, p. 240).

Analysis of Glucose.

To the fluid directly recovered from the gut were added the boiled-down washings of the loop, and the proteids precipitated by boiling with a few drops of a one-third saturated solution of phospho-tungstic acid, a procedure which does not affect estimations of glucose.

The filtrate was made up to a known volume after having been nearly neutralised, and the sugar titrated by the Allihn-Soxhlet gravimetric method, in which a measured small volume of the sugar solution is added to a large excess of boiling Fehling's fluid, the cuprous oxide collected on a tared asbestos filter, reduced to metallic copper and weighed.

For further details of this process see a previous paper ('Journal of Physiology,' vol. 20, 1896, p. 316).

Analysis of Sodium Chloride.

This was conducted by the Volhard method, using $\frac{N}{10}$ solution of silver nitrate, $\frac{N}{20}$ solution of ammonium thiocyanate, and iron alum as indicator.

If glucose is present in the solution, the titration is quite accurate if accomplished with speed, but a prolongation affects the result slightly on account of the development of nitrous acid. Proteids were removed by boiling, but small amounts do not

affect the result, as I satisfied myself by adding a chlorine-free specimen of "HARNACK'S ash-free albumen," prepared by the method of BULOW, to solutions of sodic chloride of known titre.

Lowerings of Freezing Point.

The lowerings of freezing point of solutions were estimated by the BECKMANN apparatus, and the following precautions were adopted: (i.) As little "under-cooling" as possible was allowed, and results with any very marked separation of ice were discarded. (ii.) Vigorous stirring was employed during the actual freezing. (iii.) The temperature of the freezing mixture of ice and salt was not allowed to sink below — 3° C.

Measurement of Gut Surface.

This was estimated by filling the loops with modeller's gelatine, allowing to set, and multiplying the mantle of the jelly cylinder so obtained by the length of the loop.

Since "villus factors" are of doubtful value, no attempt was made to estimate the true absorbing surface in comparison of ileum with colon.

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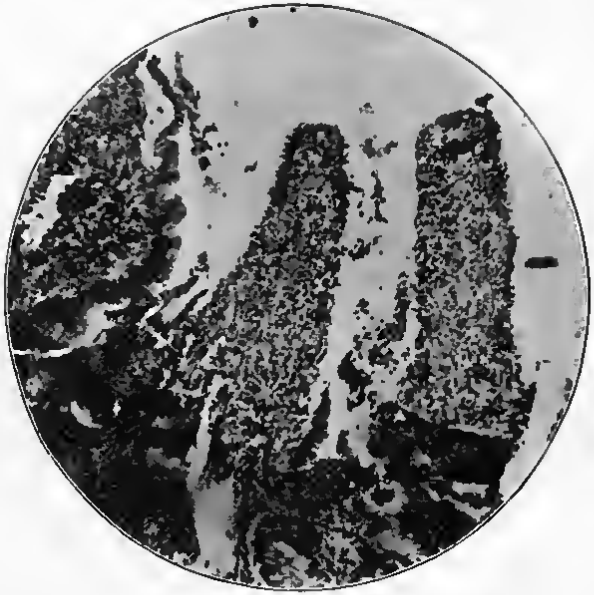
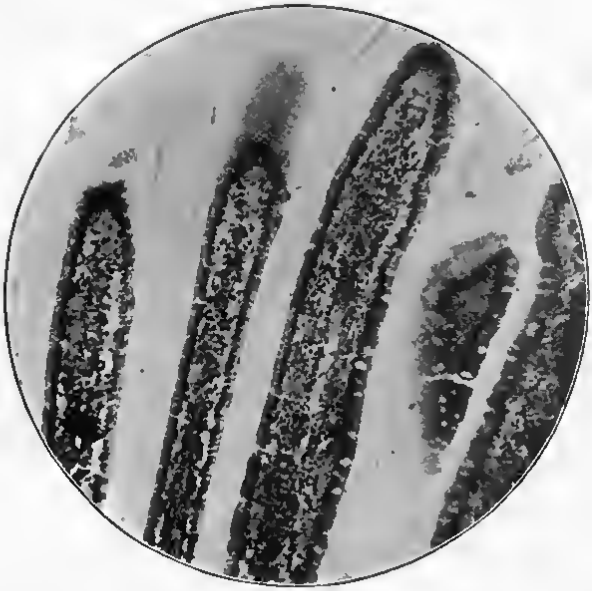
Epitome of Paper.



Epithelium of villi removed by previous anæmia.



Normal control from the same animal.

(The experiment from which these are taken was Experiment VI. in Table XII., p. 277.)